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VOLUME VII.

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WEST INDIAN BULLETIN

VOL. VII. No. 1.

AGRICULTURAL INDUSTRIES OF MONTSERRAT.

The following report on the condition of the agricultural industries of Montserrat has been forwarded by the Hon. Francis Watts, C.M.G., D.Sc., etc., Government Analytical Chemist and Agricultural Superintendent for the Leeward Islands, to the Hon. Sir Daniel Morris, K.C.M.G., D.Sc., D.C.L., etc., Imperial Commissioner of Agriculture for the West Indies. This report has been forwarded to the Under-Secretary of State for the Colonies by the Imperial Commissioner, whose covering letter is also reproduced :—

The Imperial Commissioner of Agriculture to the Under-Secretary of State for the Colonies.

Barbados,
December 11, 1905.

Sir,

I have the honour to enclose, herewith, copy of a report from Dr. Francis Watts, Government Analytical Chemist and Superintendent of Agriculture in connexion with this Department in the Leeward Islands, on the condition of the agricultural industries of Montserrat, and the manner in which the further work of the Imperial Department of Agriculture might be directed to their assistance to the best advantage.

I also enclose a diagram and table, prepared by Dr. Watts, illustrating the position of the principal agricultural exports for fourteen years,—1891-1904, inclusive.

The report is valuable as affording a clear statement of the successive stages of impoverishment that has been going on at Montserrat for many years.

The present condition of Montserrat is chiefly due to the fact that, while sugar has been steadily disappearing from the exports, no other industry has, as yet, taken its place. Montserrat, therefore, is passing through a transitional period

similar to that through which Grenada, Dominica, and many other of the West India Islands have passed in comparatively recent times.

Next in importance to sugar was the lime industry. This industry suffered severely and, in fact, was almost destroyed by the hurricane of 1899. Since then, the plantations have been more or less restored, and the export of lime juice and limes has again assumed important dimensions. It is doubtful, however, whether the lime industry can be depended upon to form, at any time, the mainstay of the people of Montserrat. As pointed out by Dr. Watts, it is now of especial importance as being, with the exception of cotton, practically the only wage-producing industry in the island.

The raising and export of stock has gradually increased of late years, and this Department has afforded assistance in this direction by the importation of improved breeds of animals.

Dr. Watts has drawn attention to the possibilities of improving the papain industry, as well as that of lime, and bay oils. He also suggests that the trade in fresh fruit and vegetables might be extended in the neighbouring islands and at Bermuda.

It is stated that, under the auspices of the Imperial Department of Agriculture, cotton growing has become an important industry, and according to Dr. Watts, upon this it would seem the development of the island in the immediate future directly depends. The value of the cotton exported in 1904-5 was £4,114, and this amount, it is anticipated, will be greatly exceeded next year. The efforts made by Messrs. Sendall and Wade in connexion with cotton growing at Montserrat deserve to be placed on record. Also the fact that there are large areas of waste land suitable for cotton still unutilized.

It is stated that there are many places in Montserrat where cacao trees are likely to thrive, and that the cultivation of Central American rubber might also be encouraged in similar localities. Although Dr. Watts does not specifically refer to it, I am of the opinion that a large and successful sisal hemp industry might be established at Montserrat. I have already suggested such an industry to the Montserrat Company. There is a large number of plants already established in the island, and it is proposed to introduce a small machine for extracting the fibre in order to obtain authentic information in regard to the quality and value of the fibre.

I would add that since this Department was created, Montserrat has received an annual grant of £550 for the maintenance of three Experiment Stations, under the charge of a Curator. In addition, the Department has provided for periodical visits by Dr. Watts and other officers, and it has furnished the means for lectures to teachers attending elementary schools, and for prizes to the Annual Agricultural Shows that have been held in the island. I estimate that the total outlay by this Department in connexion with the various

agencies to improve the circumstances of Montserrat has averaged not less than about £650 to £700 per annum.

It is only right that I should mention that the present Commissioner, his Honour F. H. Watkins, I.S.O., has been indefatigable in his efforts to assist the Department, and he deserves great credit for what he has done in the interest of Montserrat, often under trying and discouraging circumstances.

During the coming year I hope to see the several suggestions offered by Dr. Watts fully taken in hand, and I trust that within the next few years, especially on the return of seasons more favourable to agriculture, the fortunes of Montserrat will steadily improve.

I have, etc.,

(Sgd.) D. MORRIS,

Commissioner of Agriculture
for the West Indies.

The Hon. Francis Watts, C.M.G., D.Sc., etc., to the Imperial Commissioner of Agriculture.

I propose in this letter to discuss the agricultural industries of Montserrat in an effort to discover their bearing on the economy of the island, and in what manner the work of the Imperial Department of Agriculture may be directed to their assistance to the best advantage.

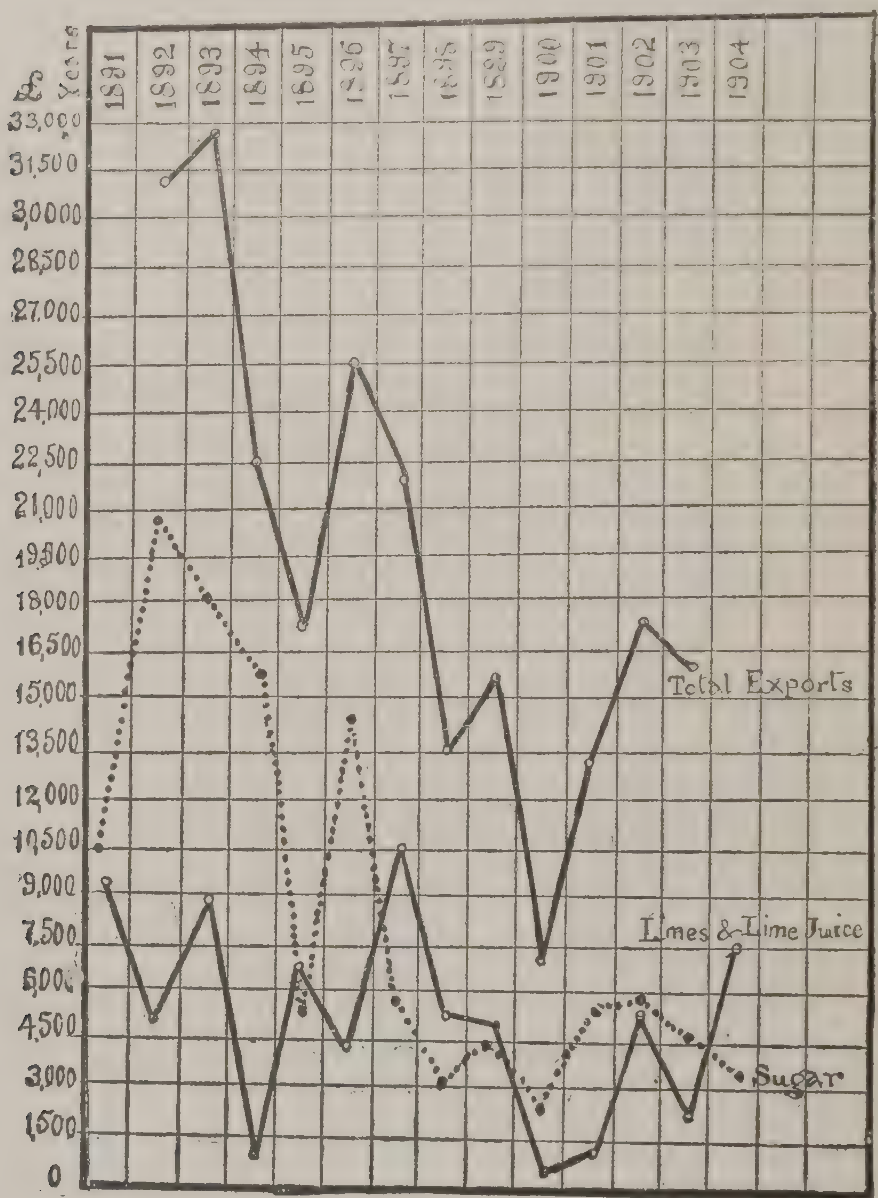
From data partly supplied me by the courtesy of the Commissioner (his Honour F. H. Watkins, I.S.O.), and partly taken from the Blue-books, I have constructed the accompanying diagrams and table showing the principal agricultural exports for fourteen years—1891-1904, inclusive.

The first thing which strikes one on looking at diagram 1 is the relatively large part which sugar formerly bore in the commerce of the island, and its comparative smallness in recent years. In the period prior to that covered by the diagram, the relative importance of sugar was even greater, for during the past twenty years sugar has been a decadent industry in Montserrat. The point to observe is that, while sugar has largely disappeared from the exports, no other industry has greatly increased to take its place. This fact is fundamental, and will have to be clearly recognized by all who are interested in the administratoin of Montserrat affairs. The traditions of Montserrat are based on sugar, and the peasantry still adhere to its cultivation in preference to anything else.

There appears to have existed an ill-defined idea, that in Montserrat, a transition has taken place, and that sugar cultivation has given place to other industries. This is not so. Sugar has largely disappeared and its place remains unsupplied. I am inclined to think that this idea was strengthened by the relative local importance of the Montserrat Company, Limited, this giving an impression that their interest in lime juice was compensating for the loss of sugar. This impression was

DIAGRAM 1.

TOTAL EXPORTS, AND EXPORTS OF LIMES AND LIME JUICE, AND OF SUGAR FROM 1891-1904.



wrong, for while cultivating little sugar themselves, the company had large interests in the sugar industry, financing various estates, shipping and dealing in practically all the sugar produced, and carrying on a general mercantile business whose basis was sugar.

Sugar has now fallen almost entirely to the level of a peasant industry, the greater part being grown by peasants on a share system. The land-owner provides the land and the sugar works, and the peasant cultivates and manufactures the sugar. Each party then takes a share of the sugar and molasses, usually one-half each. This condition leads to a low form of sugar industry from which the element of wage earning disappears. Sugar is thus very cheaply produced, for the peasant places little value on his own time, and the

land-owner spends little money beyond a small outlay on stock (cattle), and on repairs to the sugar works. The land is usually imperfectly cultivated, and is in danger of being impoverished.

So long as there is a demand for muscovado sugar, this form of industry will probably struggle on, but it is difficult to see how improvements are to be effected. The Experiment Stations can foster the introduction of the best kinds of canes, and can constantly urge the value of, and necessity for, using pen manures, composts, and manures of that nature, and also the importance of good cultivation. Here and there a cultivator of more importance than the rest may spring up, and he may be made the medium for introducing new and improved canes, and maintaining a better style of agriculture. Some attempt is at present being made in one or two directions to extend sugar cultivation on the share system. This should lead to an increased export of sugar in a year or two.

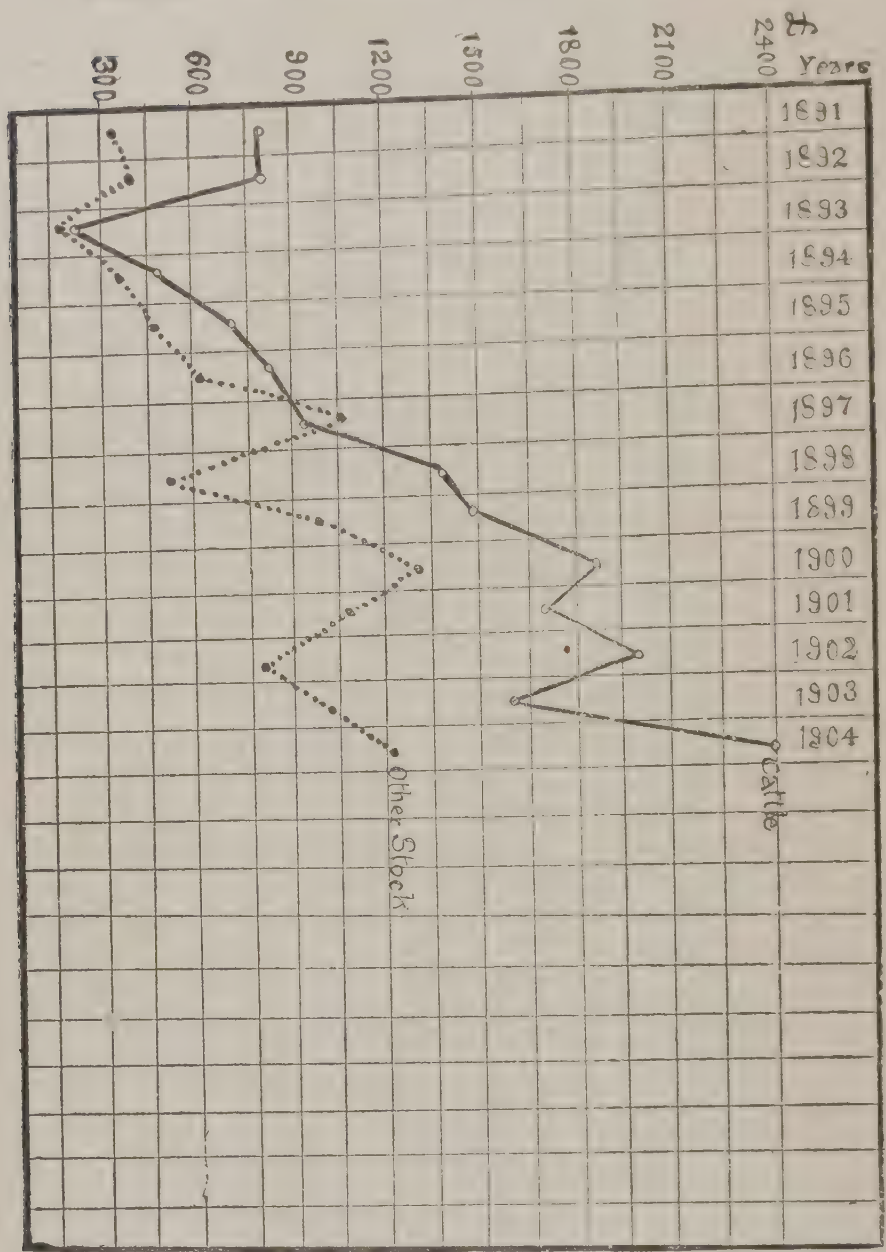
Next to sugar in importance is the lime industry. Its products are now likely to exceed the value of sugar. This industry is almost entirely in the hands of the Montserrat Company, Limited, there being no other large systematic cultivators of this fruit. The industry has passed through many vicissitudes. About twenty years ago the older plantations were dying out, largely from attacks of scale insects, which, at that time, were ill understood. New plantations were established and were in satisfactory bearing, when they were destroyed by the hurricane of 1899. Since then, with commendable energy, the plantations have been restored, so that now, the export of lime juice and limes has again assumed important dimensions, forming, in fact, the principal item in the island's trade, having doubled the value of sugar, the item next in importance.

The industry is likely to expand, provided that disasters do not again arise from the attacks of scale insects. The climate of Montserrat being drier than that of Dominica, scale insects are much more likely to cause trouble and to be less easy to control. The Montserrat Company have made extensive experiments in attempts to control scale insects by fumigating and spraying, but are, I am given to understand, doubtful of the efficiency of these remedies under the conditions prevailing in the island. Protection of the trees by means of wind-breaks, careful cultivation, and a reliance upon the natural enemies of scale insects are chiefly depended upon; direct remedial treatment being reserved for special cases. The course of events in this connexion should be closely watched by the Department of Agriculture.

The lime industry is now of especial importance to Montserrat as being, with the exception of cotton, practically the only wage-producing industry in the island.

DIAGRAM 2.

EXPORTS OF CATTLE AND STOCK FROM 1891-1904.



A glance at diagram 2 will show that, following the collapse of the sugar industry in 1895-7, there has been a steadily increasing export of animals. In 1904 the total value of animals shipped was equal to that of the sugar exported. The diagram distinguishes between cattle and 'other stock,' the latter including horses, mules, asses, sheep, goats, pigs, and poultry. The steady increase in the production and export of live stock, is, I think, the result of the failure of sugar and the consequent reduction of wage earning. It represents the effort of the peasantry to engage in some easily sustained pursuit whereby to supplement their means of livelihood, and to provide something suitable whereby they may pay for the small, but necessary, amount of imported materials clothing, tools and the like. In the absence of other

employment, and with land going out of cultivation, cattle raising becomes comparatively easy.

Something may be done to assist this effort by the importation of improved breeds of animals. To this end the stationing of the stallion 'Jamaica Lad' in the island has been useful. I was informed by the Commissioner and others that there is a demand for a good bull. Under the circumstances, I recommend that the young short-horn bull from Windsor, now in Antigua, be sent to Montserrat for a definite period, say, six months. The expenses of his maintenance to the end of the financial year, March 31, 1906, may be met from 'special services.' At the end of that time other arrangements should be made. Possibly the best thing to do will be to return the short-horn bull to Antigua and send down the Devon bull, which also came from Windsor. The bull may be kept at the Grove Station, or, under careful regulations, sent for short, definite, periods to districts where his services may be wanted.

It may also be desirable to send to Montserrat one of the Berkshire boars now at Antigua.

Diagram 3 shows that the item 'drugs' has some importance in the list of exports. This consists almost entirely of papain, or the dried 'milk' of the papaw fruit. This industry is one which has played a most useful part during the changes, which have taken place. It has provided a means whereby the peasantry have been able to earn small sums of money, which in the aggregate have been considerable.* That the industry is capable of rapid growth, if a market can be secured, is shown by the rise in the exports since 1900. The milky juice (latex) which exudes from the fruit when the skin is scored or scratched, is collected by peasantry and purchased by those who dry and ship the drug. There are three or four regular buyers, of whom the Montserrat Company are the largest. It is difficult to over-estimate the importance to the peasantry of the money thus put into circulation. Some idea may perhaps be formed from the fact that the milk is carried for miles, from the place where it is collected, to the buyers. The money so spent probably constitutes the largest direct form of monetary payment that has reached the peasantry during the past two or three years.

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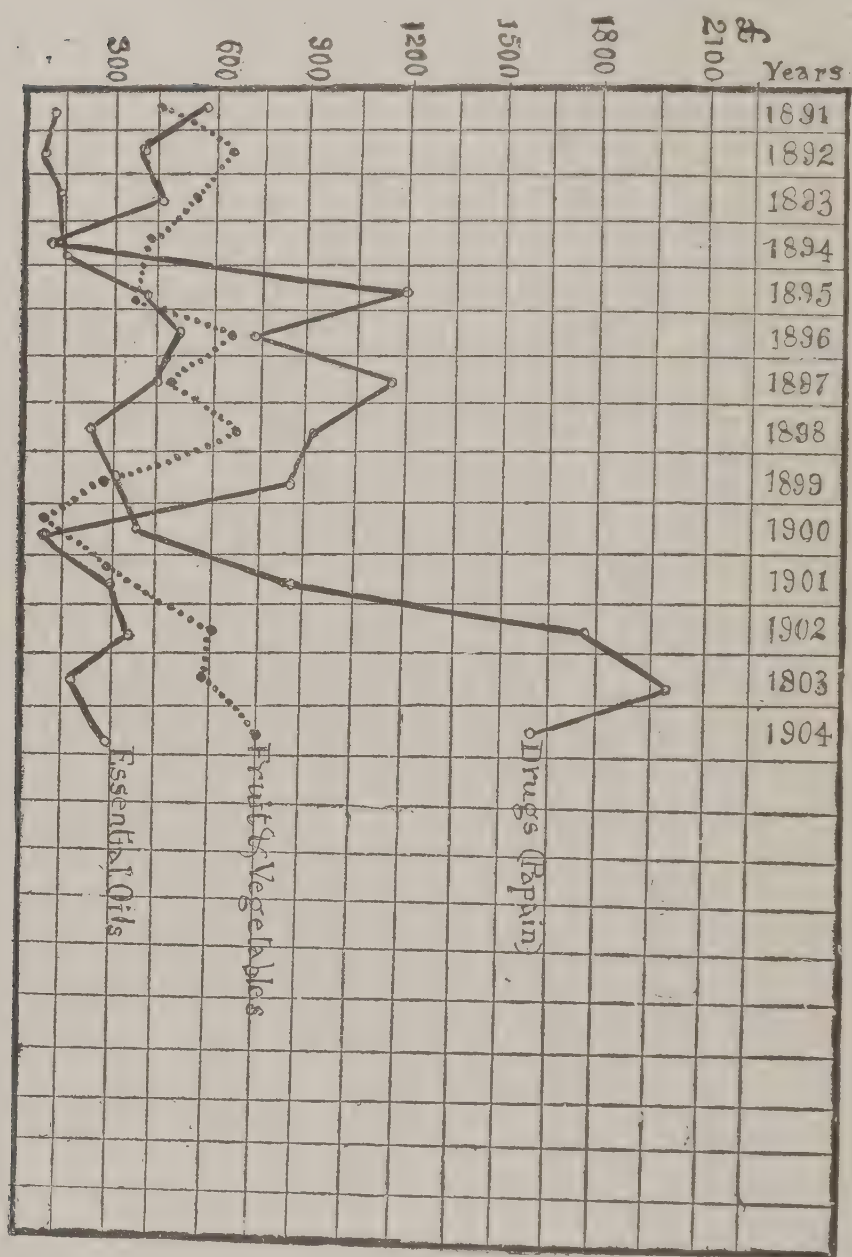
* I am particularly interested in this industry, as I personally introduced it many years ago and after a good deal of preliminary work was able to place the method of preparation on such a footing, that it can be carried on with little skilled supervision.

DIAGRAM 3.

EXPORTS OF DRUGS (PAPAIN), FRUIT AND VEGETABLES (EXCLUSIVE OF LIMES), AND ESSENTIAL OILS FROM 1891-1904.



I am informed that work in connexion with this industry is suspended, owing, it is stated, to the flooding of the market with large supplies from the East. In some quarters it is suggested that this competition has been increased, if not created, by the article which I wrote for the *Agricultural News* (Vol. I. p. 4). This is, however, somewhat improbable. The attempt has been made on the part of the people in Montserrat to treat this industry somewhat as a secret one. This is a position which cannot long be maintained. I think the time has now come when the Department of Agriculture should make inquiries into the nature and extent of the market, and its

requirements, when, possibly, means may be formed for restoring the industry to Montserrat. The people have acquired a considerable degree of skill in collecting the drug, and an abundant supply exists at present unutilized. Under these circumstances, it may be that the efforts of an organization of the character of the Department of Agriculture may assist in consolidating the trade and restoring the industry to Montserrat. I suggest, therefore, the desirability of your communicating with firms dealing in this drug, or with persons who are familiar with the drug trade, with the above-named object. In this connexion, the names of the American Ferment Company, of New Jersey, U.S.A., and of Mr. J. R. Jackson occur to me. You will perhaps add others.

Essential oils were at one time exported in appreciable quantity. These were hand-made and distilled lime oils and bay oils. Owing to the fall in price of hand-made lime oil, little is now prepared, while but a small amount of distilled oil is produced, because much of the lime juice has been shipped in the raw state, distilled oil being a by-product in the process of preparing concentrated juice. With the restoration of the lime industry, it is probable that the production of distilled lime oil will again increase.

The preparation of bay oil is carried on in a crude and unorganized manner. It seems possible that this industry could be put on a better footing both as regards the growing of the leaves and the distillation of the oil. It is with this object in view that there is a small plot of bay trees being raised in bush form at Harris' Experiment Station, and it is partly in order to study the problems connected with the distillation, that I wish to have a 'still' large enough to conduct distillations on a small commercial scale. The still will also enable me to study questions relating to the production of lemon grass oil, concerning which there has been much correspondence, but from which little has resulted through lack of precise information and the inability to prepare samples on a commercial scale.

The trade in fresh fruit and vegetables (not including limes) is chiefly one with the neighbouring islands. It is worth inquiring whether the fruit trade with Bermuda may not be extended. The small trade in onions also falls under this head. At present it has not assumed important dimensions.

Cotton growing has now become an important industry, and upon this it would seem the development of the island in the immediate future directly depends. In 1903, the output was valued at £1,486; in 1904, it was £1,380, although the area under cultivation was larger than in the previous year; the diminution being due to diseases and pests, largely leaf-blister mite, a new disease, at that time not understood. This disease is now capable of control, so that in 1905, the value of the cotton exported rose to £3,486,* and this amount should be greatly exceeded next year.

* Estimated value of cotton exported for the period ending September 30.

TABLE I.

PRINCIPAL EXPORTS, 1891-1904 (INCLUSIVE.)

	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
	£	£	£	£	£	£	£	£	£	£	£	£	£	£
Cattle	792	798	195	569	677	804	951	1,362	1,485	1,861	1,693	2,007	1,618	2,390
Other stock	358	374	186	337	460	619	1,059	518	976	1,316	1,079	796	1,042	1,218
Fruit and other vegetables (fresh) ...	466	653	540	427	387	634	480	218	275	80	283	601	591	727
Lime juice and limes	9,418	4,859	8,844	729	6,802	4,261	10,364	5,154	4,926	368	1,110	5,465	2,342	7,803
Sugar	10,417	20,559	18,249	15,930	5,252	14,437	5,685	3,074	4,416	2,052	5,241	5,433	4,592	3,656
Drugs (papain) ...	115	84	133	148	426	501	451	649	281	359	866	1,763	2,000	1,627
Essential oils	567	399	463	108	1,182	722	1,158	937	863	56	299	345	188	287
Cotton	...	...	...	...	...	...	...	...	...	...	...	...	1,486	1,380
Total exports (excluding coin and bullion.)	...	31,013	32,715	22,502	16,889	25,402	21,193	13,549	15,569	7,315	11,393	17,405	15,974	21,140

There are about 800 acres under cotton in the island for the present crop. Of these, 500 acres are on the estates controlled by Messrs. Sendall and Wade; 200 acres on the estates of the Montserrat Company, and about 100 or so in the hands of other growers. From this it would seem that cotton has not yet become a generally accepted, or widely diffused industry in Montserrat. This condition should be altered if possible. There is still a considerable quantity of land, at present not remuneratively occupied, suitable for cotton. If this season's work prove profitable, doubtless the larger land-owners will extend the cultivation of cotton, while some of the smaller holders, who are now interested in the cultivation of sugar on the share system, may be induced to plant cotton. Under the share system, with sugar the land-owner risks nothing beyond the very small outlay for keeping his sugar works in indifferent repair. His share of the sugar produced by his clients is largely profit, being in the nature of rent for land which otherwise would be unoccupied. While the peasant employs his spare time in growing canes, incidentally he grows articles of food and raises cattle or other animals, so that his cane may almost be regarded as a savings' bank for his spare time. The sugar thus produced can, to a large extent, be used as a local article of food, and so, in the last resort, is never an unsaleable article. To change this system for a cotton industry implies a considerable alteration in habit. Besides, cotton is an industry which requires more skill and attention than sugar—skill and attention which the peasant has not yet learned to bestow. Nevertheless, it is in the direction of cotton that we have to look for any considerable and immediate improvement in Montserrat.

Prior to the hurricane, attempts were being made to establish small plantations of cacao. Most of these were destroyed by the hurricane, and in most cases the owners were too discouraged to endeavour to restore them. The Montserrat Company have, however, taken in hand the restoration and extension of a small plantation at Woodlands, which promises to be very successful; thus setting an example which deserves to be followed.

There are many places in Montserrat where cacao will thrive and where efforts should now be made to introduce it. I am inclined to think that in the past, in Montserrat, cacao was rather regarded as requiring, or at least suitable for, rather high elevations, so that places at low elevations, which might be suitable, were neglected. The time has now arrived when the Curator and other officers of the Department of Agriculture should look out for suitable spots and endeavour to induce the owners to plant small numbers of cacao trees. It would be good policy to provide a number of trees gratuitously, if it can be ensured that proper planting in suitable districts is undertaken, and that the trees are properly looked after. The development might well form one of the duties of the Curator. Once the idea takes hold, and the trees begin to thrive, the self-interest of the owner will ensure further progress.

Suitable places are to be found in no inconsiderable area along the main road leading from Plymouth to Harris'. Here

there is a series of ravines, wherein, I feel sure, many acres could be found suitable for the end in view. Some of this land I found was in charge of Mr. C. Watson. I mentioned the matter to him and found him sympathetic. A start can therefore be made there, and I have asked the Curator to procure cacao seeds and plants, and to endeavour to co-operate with Mr. Watson in getting a small amount of pioneer work started. I hope to be able to influence others also to make experiments.

In addition, there are many suitable places around St. George's Hill, and in the ravines on the eastward slope below Harris'. I feel convinced that much good work can now be done in this direction, if the Department of Agriculture take it steadily and systematically in hand. The work must progress slowly for many reasons. There is not much money available; the work is somewhat of an experimental nature; planting will probably only be successful in pockets and sheltered places; wind-breaks will have to be planted and grown, and, finally, the idea is new to the people concerned, and their interest will be but slowly awakened.

It is in connexion with this that it is unfortunate that the cacao trees at Harris' have been neglected.

There are now in Montserrat a few trees of Central American rubber (*Castilloa elastica*) of sufficient age and growing sufficiently well to lead one to suppose that this tree can be successfully grown in the island. This is a point of some importance, and its bearing should be carefully kept in view. Owing to the fact that a Castilloa tree has to be some eight years old before it is fit to yield rubber, it will be recognized that there is not likely to arise a great enthusiasm in connexion with it on the part of small proprietors, who have little or no ready money. Still, I believe the Department of Agriculture, by steady effort, can ensure the planting of a considerable number of these trees within the next few years. In fact, I do not think there will be much difficulty in usefully disposing of all the Castilloa trees which can be obtained. This, while having little immediate effect, may be of very great importance to Montserrat in the course of a few years. The matter is therefore one which should be steadily and systematically kept in view, one which the Curator and other officers should have steadily in their minds and carefully foster.

I am informed that the Montserrat Company have decided to discontinue the production of arrowroot for export.

It may be interesting to draw attention to the circumstances of the people living in the northern district of Montserrat. The almost abandoned lime estates of Olveston and Woodlands interpose a very sparsely inhabited or almost entirely uninhabited tract between the villages of Salem and Church Hill. Lying beyond and northward of Church Hill there exists a somewhat isolated and self-contained community, largely consisting of peasant proprietors, or of peasants cultivating land on a share system. These people suffered severely in the hurricane; all their houses and practically all their belongings were destroyed. They have now built up the elements of

a small peasant community, which has no means of wage earning, but which grows its own food and obtains the small amount of money necessary for the purchase of clothing, tools and the like, from its small exports from the district. These exports consist of sugar, grown and manufactured on a share system; of vegetables taken to the village markets in other parts of the island; of small numbers of cattle, horses, and small stock: and of vegetables and fruit, chiefly bananas, shipped to Antigua. All these exports are small, but they suffice for the modest requirements of the district. This district will probably feel somewhat acutely the loss of the papain industry. The conditions of life here are on a comparatively low plane, but they are interesting as illustrating what results from a peasant proprietary, cut off from the power of wage earning by the absence of regular estates employing labourers. The habit of wage earning has been weakened or lost. This is seen by the fact that, when a short time ago the Montserrat Company planted a small area in cotton in this district, difficulty was found in obtaining labour, and comparatively high rates had to be paid. The resources of such a district are few, civilizing influences are apt to weaken, roads are likely to be poorly kept, public works, in the way of bridges, buildings or improvements will be difficult to secure, and the governmental administration will have to come down to a similarly low level. Such conditions remind me of those prevailing at Tortola, where, while there is practically no poverty, life is on a low level, and progress is slow or absent.

A district so constituted is liable to rapid fluctuation in its prosperity. A drought means starvation and distress from want of resources; propitious seasons as quickly restore the small measure of prosperity.

With a peasant-proprietary body, the exports of a community will be small; the individuals will be chiefly engaged in raising food, and in producing a limited quantity of articles for export, in order to supply the small amount of clothing and the tools and implements, which must be imported. Should the tendency be towards extensive exports, the peasant-proprietary system, by the acquisition of property, will pass into the 'estate' system. A peasant-proprietary community may be in a prosperous condition and yet show small exports. One must therefore avoid the fallacy of judging the prosperity of these communities solely on the basis of exports.

It would appear best for these islands that there should exist both a system of estates, providing means of wage earning; and also a peasant-proprietary body, which will form a useful sort of middle class, whence, it is possible, a supply of labourers may be drawn. Such a combination of an estate system with a peasant proprietary appears to afford the conditions most likely to prevent retrogression and to lead to progress, at the same time providing those elements which will enable the general affairs of the island, political and social, to be conducted and maintained on happy and dignified lines. It will be well, then, to foster those elements, which tend to preserve the 'estate' system. Fortunately, the cultivation of limes and of cotton succeeds the best on 'estate' lines.

In addition to the diagrams 1, 2, and 3, giving details of the principal items of export from 1891 to 1904, I have prepared diagram 4, showing the total exports from Montserrat from 1868 to 1903:—

DIAGRAM 4. (Corresponding with Table II.)

TOTAL EXPORTS (INCLUDING COIN AND BULLION) FROM 1868-1904.

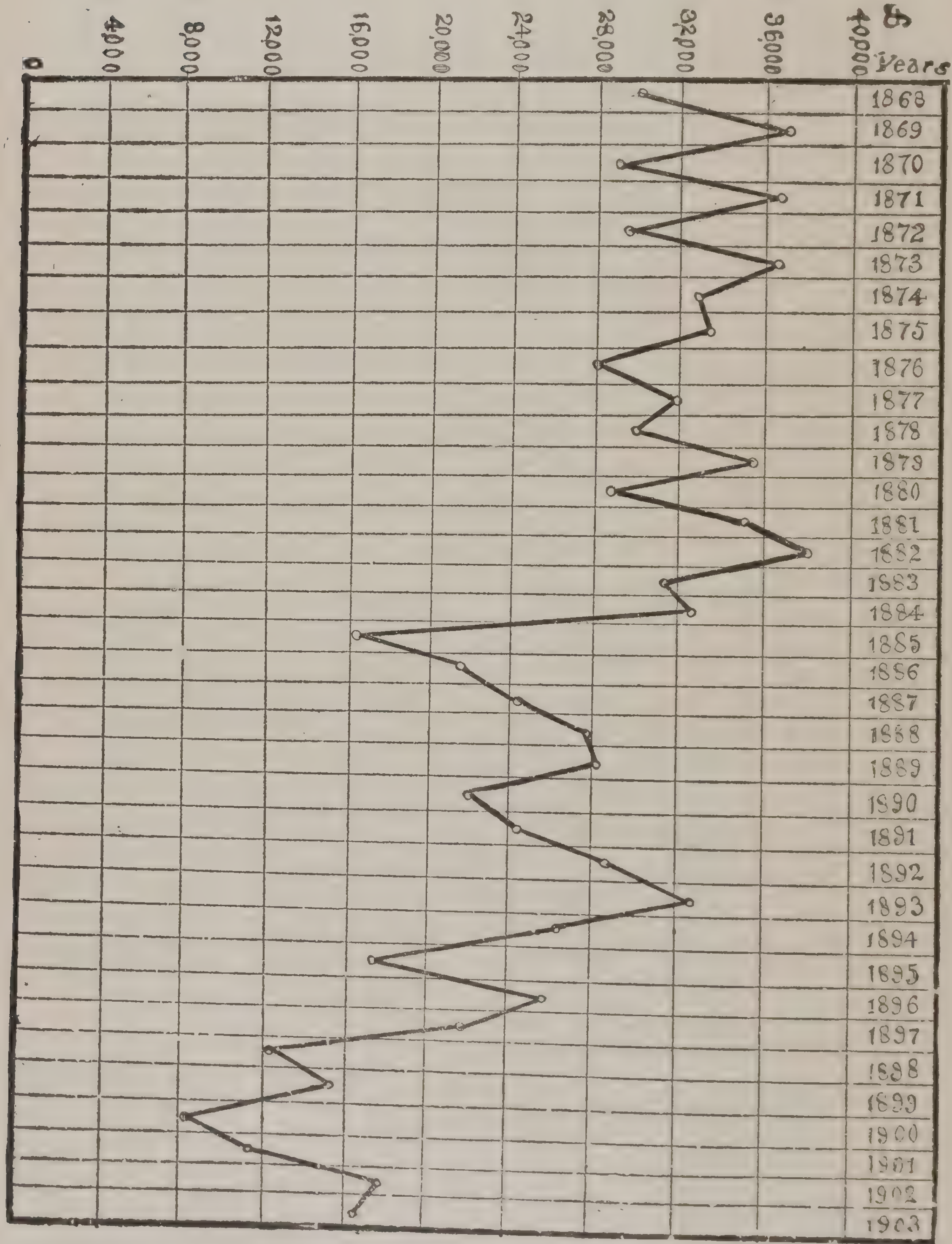


TABLE II.

TOTAL EXPORTS (INCLUDING COIN AND BULLION) FROM 1868-1904.

Year.	Exports.	Year.	Exports.	Year.	Exports.
	£		£		£
1868	30,279	1881	35,205	1894	22,462
1869	37,228	1882	38,120	1895	17,389
1870	29,141	1883	31,494	1896	25,929
1871	36,069	1884	32,677	1897	22,059
1872	29,736	1885	16,284	1898	12,240
1873	36,783	1886	20,944	1899	15,569
1874	33,079	1887	24,216	1900	8,287
1875	33,554	1888	27,874	1901	11,268
1876	28,063	1889	28,392	1902	17,718
1877	32,065	1890	21,876	1903	16,424
1878	30,239	1891	24,399	1904	21,640
1879	35,685	1892	28,829	—	—
1880	29,191	1893	32,715	—	—

On comparing diagram 4 with the corresponding table, it will be observed that from 1868 to 1884 the exports oscillate fairly regularly about a mean of some £33,000, never rising above £38,120, nor falling below £28,063. The steady oscillations of this period appear to be dependent upon the sugar crop. In 1885 the exports fell to nearly £16,000. This was due to the collapse of sugar, and at this period several estates went out of cultivation, or largely diminished their output. From that time onward the rises and falls indicate the struggle made to maintain the sugar industry. The rise of the exports to over £32,000 in 1893 indicates the period when an effort was made to revive the cultivation of the important group of estates known as the 'Irish Estates,' together with others. These efforts failed, and sugar, after various struggles, is now an industry of little general importance, though still second in magnitude amongst the list of exports from the island. It is doubtful if the sugar industry of Montserrat will attract sufficient capital to equip it with modern machinery to enable it to compete successfully with the industry as carried on in larger places, so that it seems probable the industry will not assume any magnitude. Present indications would point to its place being largely taken by cotton during the next few years.

This review of agricultural affairs in Montserrat may, I trust, prove useful in indicating the general trend of events, and in helping to ascertain how the work of the Department of Agriculture can be applied in assisting an interesting but struggling presidency.

EXPERIMENTS WITH RUBBER-YIELDING PLANTS IN DOMINICA.

BY JOSEPH JONES,

Curator, Botanic Station.

CENTRAL AMERICAN RUBBER.

Shortly after the Botanic Station was started (1891), a few plants of this rubber tree (*Castilloa elastica*) were imported and planted in the garden. These were the first rubber plants of this species imported into Dominica. From them many thousands of seedlings have been raised and distributed to planters in Dominica, and to the Botanic Stations at Montserrat, Antigua, St. Kitt's, and Tortola.

The original plants—four in number—were planted along the edge of a small field of cacao. They grew well, and now at thirteen years of age, average 55 feet in height and 5 feet 7 inches in girth at 3 feet from the ground.

TAPPING.

Tapping experiments were made on one tree in 1903, an ordinary knife being used to make slits in the bark. Over 1 ℔. of rubber was obtained. This was submitted to experts and pronounced very good, but dark in colour. It contained rather a high percentage of resinous matter, probably due to insufficient washing. The value, on the basis of prices then existing, was reported to be 2*s*. 11*d*. per ℔.

This was considered a very unsatisfactory method of tapping, and therefore, early in 1904 the Imperial Commissioner of Agriculture obtained from Ceylon a tool (fig. 4, p. 21), in use there for tapping rubber trees. A description of it has already appeared in the *West Indian Bulletin* (Vol. V, p. 216). It was tried in Dominica and found an efficient instrument for Castilloa trees. Figs. 1 and 2 show trees tapped with it.

The trees were lightly tapped with it, one-half of the circumference of the trunk being operated on, and they gave a yield of 1 ℔. per tree. The rubber was examined by an expert, who reported that the process adopted for coagulating the latex was entirely satisfactory, and the vulcanizing qualities were very good indeed. The colour was very dark, but this could hardly interfere with the price. This sample was valued at 5*s*. 6*d*. per ℔., delivered at London or Liverpool.

During the present year (1905) tapping experiments were continued, the instrument used being a plain iron chisel. A good flow of latex resulted and some excellent sheets of rubber were prepared, but they have not yet been reported on. Owing to improved methods of washing, it is thought this year's rubber will be the best yet produced at the station. In the previous year's experiments (1903-4) the latex had been treated in a wooden vessel. It was thought this accounted for the dark colour of the samples. Therefore this season, an enamel-lined vessel, fitted with a tap below, was substituted, but no improvement in the colour of the rubber has resulted. Other experiments to improve the colour are now in progress.

METHOD OF TREATING THE LATEX.

The treatment of the latex has been uniform in all the experiments, except that during the present year improved methods of washing have been tried. These are expected to reduce the amount of resinous matter in the samples. The method of procedure was as follows:—

After tapping, the latex was mixed with water and afterwards strained through cotton gauze to remove pieces of bark, etc. A small quantity of formalin was added as a preservative to the milk, which was then stirred, poured in a special vessel, and allowed to stand.

The rubber, white in colour, slowly rose to the top, and the water, then a black looking liquid, was run off gradually from below. As soon as this black liquid had all drained away, the rubber cream began to harden, and rapidly darkened in colour; it was then thoroughly washed and dried.

This year thorough washing was carried on in both the liquid and rubber stages. As soon as the liquid had been drawn away, a knapsack sprayer fitted with a vermorel nozzle was turned on the creamy mass with great force, and the whole thoroughly churned. The setting process then followed, and the water was again drawn off. This was repeated several times. It is expected that this washing at both stages will considerably improve the samples.

METHODS OF TAPPING.

Three different methods of tapping have been experimented with. The instrument obtained from Ceylon was used in two of these, while the other was carried out by means of an ordinary chisel and mallet.

The first method was a modification of what is known as the 'herring-bone.' A main channel is cut vertically from the base of the trunk to a height varying from 2 to 5 feet, according to the size of the tree. From this central incision, lateral inclined incisions are made at regular distances apart, to the right and to the left.

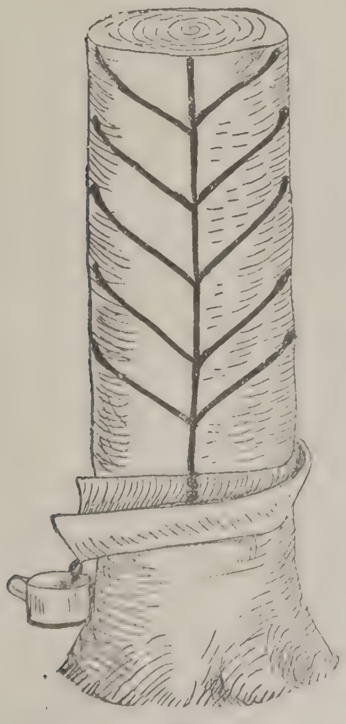


FIG 1.

The vertical channel is merely a conduit for the latex, which runs down into a spout fixed at the base of the tree. Fig. 1 illustrates a tree tapped by this method.

It has been recommended on account of the labour saved in having no cups to fix, and in being an easy way to collect the latex. The central channel, however, has a tendency to become blocked, through the coagulation of the latex in it. Therefore a large amount of 'scrap' rubber is produced.

The second method adopted is by making a number of oblique lines, about 18 inches apart, on one half of the circumference of the trunk of the tree (fig. 2). There is, therefore, much less cutting than in the first method, and an equal yield of latex is obtained, as the lactiferous vessels are drained for a considerable distance above the point tapped, and therefore cuts need not be made so close as advocated in the 'herring-bone' method.

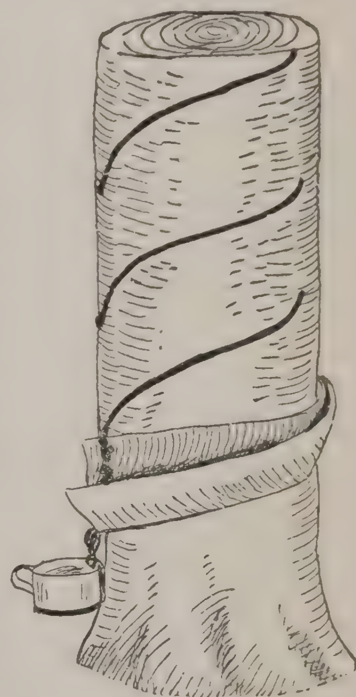


FIG 2.

In the third method used, the incisions are made by means of a chisel driven in by a mallet. Each incision is from 1 inch to 2 inches long (varying with the size of the chisel used), and is horizontal. Starting on the left side of the trunk the lowest cut is made just above the fixed spout, and each successive one is then made at a slightly higher level and to the right, until an oblique line of horizontal cuts is made on one-half of the trunk. At distances, varying from 8 to 12 inches above this line, are made others in the same way to a height of from 4 to 5 feet from the ground. The whole arrangement therefore presents a half spiral of horizontal cuts on half the circumference of the trunk, with a distance of from 8 to 12 inches between the lines of the spiral (fig. 3).

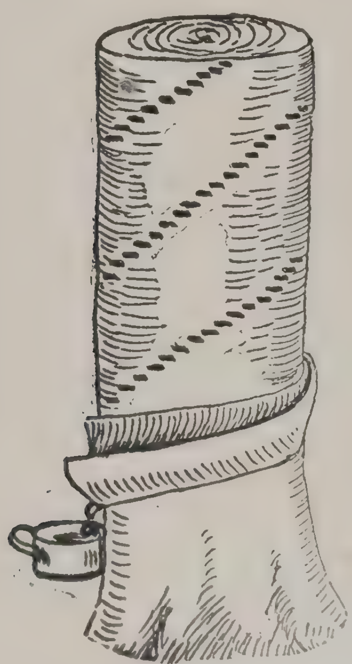


FIG 3.

The chisel must be driven in and withdrawn at one level. No prizing, or up and down movement of the hand grasping the chisel should be attempted, as is sometimes done to widen the aperture in the trunk, in the hope of causing a greater flow of latex. The chisel should enter the bark straight and be withdrawn straight. If the incision is widened by movement of the chisel, it cracks the bark, which dies for a considerable distance around the wound. Careless tapping of this character would throw a tree into a bad state of health.

When the chisel is carefully driven in, a good flow of latex is obtained with a very small cut; little damage is done, and the wound heals quickly.

COLLECTING THE LATEX.

This must be done with great care or much loss of rubber results. In the earlier experiments small tin cups were used, but were found unsatisfactory. Later a piece of tin, made to

form a channel, was placed near the base of the trunk ; the milk ran in this, and was discharged in a vessel standing on the ground. This tin channel had to be tacked to the bark. As it was not pliable enough to enter the depressions in the trunk, a quantity of clay had to be used to fill up the interstices. The latex was successfully obtained by this method, but the cost of the pieces of tin, and the difficulty of fitting them to the trees were serious drawbacks.

It is now found that the best and cheapest method of providing a channel for catching the milk is by the use of the sheathing bases of the leaf-stalks of the cabbage or similar palms. These are naturally hard and dry, and should be soaked in water a few hours before being used. They then become pliable and can be tacked on to the tree in and out of the irregularities of the stem, so that very little clay is required.

When the tree is tapped, the latex, which readily flows down the bark, is caught in the channel and conveyed to the collecting vessel. The trunk should be washed down with water, for if this is not done a very small portion of the latex will find its way to the vessel, as it speedily hardens on the trunk and forms scrap rubber. This washing is best done with a knapsack sprayer fitted with a vermorel nozzle. The whole trunk can be thoroughly washed and all the milk easily secured by the use of a very small quantity of water.

LAGOS RUBBER.

This rubber tree (*Funtumia elastica*) was introduced into Dominica in 1896. A small plot of thirty trees was started during the following year, but most of them were uprooted during the gale of 1903. An experimental tapping was made on the few trees that remained, the method followed being the same as with Castilloa, except that the slits in the bark were made with an ordinary pocket knife. The stems were afterwards washed down with a sprayer, the liquid strained to remove pieces of bark, etc., and a little formalin added. The whole was then gradually heated in an earthenware vessel over a fire, and coagulation effected in a few minutes. The rubber was then lifted out, pressed, washed, and dried. A small cake of what appears to be fair rubber, of a good colour, was obtained.

RELATIVE MERITS OF CASTILLOA AND FUNTUMIA FOR PLANTING IN DOMINICA.

Castilloa elastica thrives excellently in Dominica, and there is every indication that the yield will be satisfactory. It is generally stated that Castilloa will do well wherever cacao grows. This may be taken as a guide by planters in Dominica. Where shade is required for cacao, Castilloa may be planted to furnish it. This tree could also be planted along the edges of cacao fields. Cacao trees growing near to Castilloa at the Botanic Station for the last twelve years have borne as well, and look as healthy as cacao growing outside the area occupied by the Castilloa roots.

When a plantation of Castilloa is started, it is desirable that a good position, well sheltered from the wind, should be

selected, for constant exposure to prevailing winds greatly retards the growth of the plants. Close planting in order to cover the ground quickly and to keep down weeds is recommended, the redundant plants being cut out as the permanent ones require more room. In many cases the young plants thus removed will yield a fair quantity of rubber.

It has been noticed that when severe storms have swept over the island, Castilloa branches are seldom broken, and the trees never uprooted. These are important points in its favour. A matter of this kind has not to be considered in islands like Tobago and Trinidad, which are situated outside the area of severe storms: but to planters of Castilloa in the Northern Islands, the indications that a plantation of this rubber will not be severely injured by a passing great gale are very important. Both the Hevias and Funtumias are somewhat easily uprooted by storms in Dominica.

Castilloa plants, especially when young, are liable to attacks of a scale causing white blight. Where the conditions are favourable for the tree, the insect does not appear to do much harm.

Funtumia elastica, the Lagos silk rubber, is a slender-stemmed tree, of fairly rapid growth. It requires a well-sheltered position, as it is liable to be uprooted during heavy gales. It is sometimes attacked by black blight. Nothing is yet known as to its probable yield. Although a promising tree under certain conditions, and the preparation of its rubber is easy, it cannot yet be generally recommended for cultivation like Castilloa. The latter is undoubtedly the more suitable for cultivation in Dominica.

RUBBER EXPERIMENTS IN ST. LUCIA.

BY J. C. MOORE,
Agricultural Superintendent.

CENTRAL AMERICAN RUBBER.

Experiments in tapping rubber trees (*Castilloa elastica*), and in the preparation of samples of marketable rubber have recently been carried out with promising results at the Botanic Station. There are at the station nine trees, of which the largest and oldest, referred to as No. 1, appears, from records available, to have been planted about seventeen years ago. There is no definite record of the age of the remaining eight trees, but evidence seems to indicate that they are about fifteen years old. As will be observed from the tapping results, these trees are, on the whole, very poor specimens for their age, their slow development being accounted for by the swampy nature of the land they occupy, a condition as inimical to the growth of Castilloa as it is unnatural. The best tree, No. 1, is on slightly higher ground than the others, and occupies the best position as regards quality of soil and drainage. Then follow, in the order of development, Nos. 8 and 9. These occupy the best positions in the row and are growing along the bank of the main drain, which is daily flooded with tidal water. The remaining six trees are exceedingly poor specimens. With the exception of the methods employed in tapping Nos. 8 and 9, it was considered inadvisable, with such a small number of indifferently developed trees, to attempt tapping experiments of a comparative nature with the hope of obtaining useful results. The work done, therefore, was more of the nature of trials of tapping implements and methods adopted by others, with the object of gaining experience.

TAPPING IMPLEMENTS.

The small triangular-shaped tapping tool (fig. 4) obtained from Ceylon (See *West Indian Bulletin*, Vol. V, p. 216) was tried, but was considered to be too light and fragile for useful

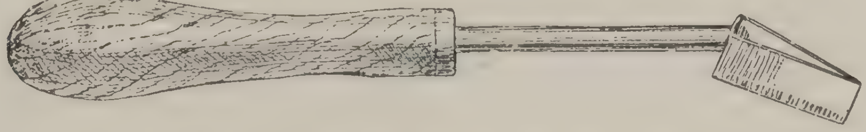


FIG. 4. Tool for incising Rubber Tree.

work. The small angular cutting blades readily choked with wedges of bark, removed in making an incision.

A 2-inch chisel and mallet did good work, but the objections to their use were (1) the necessity for carrying two tools; (2) the time lost in making the several cuts required to complete an incision; (3) the splashing of the latex, caused by driving the chisel.

A trial was made of a knife (fig. 5) lent by Mr. Hudson. This consisted of a round, pointed, double-edged blade, which

could be extended from, or withdrawn into the hollow iron handle by means of a milled nut, with the object of regulating

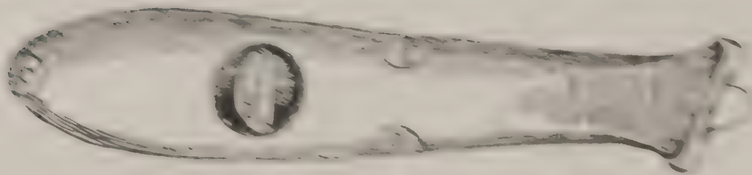


Fig. 5. Knife for tapping Rubber Tree

the depth of the cut. This knife required good strength to use it (at least two strokes to complete an incision), and was not easily guided. A description of this knife is given in the *Agricultural News*, Vol. II, p. 282.

The most satisfactory implement so far used is an invention by Mr. Hart of Trinidad. This has two V-shaped cutting edges at different angles for narrow or wide incisions. It is strongly made, and sufficiently heavy to work smoothly, and an incision can be made by a single stroke.*

METHOD OF TAPPING.

Tin cups of about 1 pint capacity and semi-circular in shape were used, each being fastened to the tree by a ½-inch tack passing through a hole in the back of the tin, which was slightly curved to fit the tree.

Moist clay was used to form a water-tight union between the tin and the bark and also at the corners of the cup to guide into it the latex that overflows the edges of the incision.

The cups were placed a foot apart in rings around the stem, these rings being from 1 foot to 2 feet above each other, according to the size of the tree, and the cups in one ring were arranged alternately with those in the ring immediately above. About 8 inches above each cup, V-shaped incisions were made, each separate cut being about 4 inches long, and at an angle of about 45 degrees (fig. 6).† At the top of the V, the cuts were about 7 inches apart, converging to within an inch or so at their lowest points.

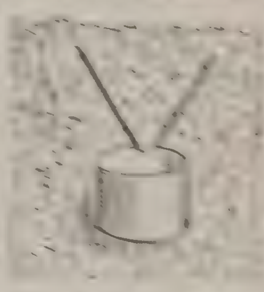


Fig. 6. Incisions and tin attached.

It was found necessary to secure the cups before incising, as the latex ran so freely at first as to result in considerable loss if this were not done. The tapping in each case was commenced above and worked downwards.

Sufficient water to cover the bottom of each tin was put in to keep the latex liquid. In most cases, it continued to flow slowly for about one hour, at the end of

* It is hoped that a figure of this instrument will be given at some future date. [Ed. W.I.B.]

† In looking at figure 6, it will be noticed that the cup is immediately below the incisions. As the cup has to be fixed before incising, it is found that the cut can only be made conveniently some distance above the cup. Mr. Moore finds that 8 inches is about the most convenient distance. [Ed. W.I.B.]

which time any rubber adhering to the cuts or bark was washed into the tin by a brush, which was made by bruising one end of a 6 inch piece of the petiole of a partly dried plantain leaf. This makes an effective and inexpensive brush for the purpose and can be replaced as often as required.

This washing down is necessary, as a considerable quantity of rubber would otherwise have been left on the trees to become 'scrap.'

TREATMENT OF LATEX.

The cups are then emptied and rinsed into a clean bucket, and the already diluted latex is further diluted by the addition of about an equal volume of water. The whole is then strained through a fine-mesh wire sieve.

The further treatment of the latex in the preparation of the rubber is described in the following copy of a report addressed to the Imperial Commissioner of Agriculture, with reference to samples weighing about $3\frac{3}{4}$ lb. and marked 'A.,' 'B.,' 'C.,' which were forwarded in October 1905, for valuation :—

'*Sample A.*—To the latex, after dilution with water and straining, was added formalin, at the rate of $\frac{1}{6}$ oz. per gallon. It was then allowed to stand in a small tub for about thirty-six hours, when the liquor under the supernatant rubber was drawn off. The rubber was again diluted to a similar bulk, with water only, and allowed to stand for about forty-eight hours, after which time it was found that the rubber was only slightly granulated, and not agglutinated into a mass of sufficient strength to be handled. After drawing off the water, the thick rubber cream was poured into a blotting-paper filter, fitting into a flower pot, in the bottom of which was some fine sand. By this means the water drained away from the rubber, which, in about forty-eight hours, could be lifted out of the filter, and the greater part of the paper peeled off. On the rubber drying still further, any adhering particles of paper were washed off, and the rubber was finally dried.

'*Sample B.*—As the non-agglutination of the rubber when treated with formalin in my initial experiments, appeared to be a serious drawback to its cheap preparation, a trial was made without the use of formalin. It was found that after treating the latex in a similar manner, but with the omission of the formalin, the greater part of the rubber agglutinated readily on top of the liquor after standing for two days. After decanting the liquor and removing the agglutinated rubber, the small quantity of rubber which remained in the milky condition was washed into the tub receiving that day's tappings. By this means none was lost. The rubber, which was removed in a spongy mass, was well washed by kneading in clean water. After allowing it to stand in several changes of water for a day, it was taken out, worked with the hands to remove as much liquor as possible from the pores of the cake, dried with a cloth, and exposed in an airy room.

'*Sample C.*—This sample consisted of the scrap rubber, which was left on the trunk of the tree through not having been washed into the tins.'

DESCRIPTION AND VALUATION OF SAMPLES.

All the cakes of drying rubber required wiping every day, to remove any moisture that accumulated on their surfaces.

Sample A., after about five weeks' drying, was of a brown colour outside, but quite white inside.

Sample B., after about four weeks' drying, was of a dark-brown to a black colour outside, but quite white inside.

Sample C. was simply scrap rubber gathered from the incisions a day or two after tapping.

These samples were sent to experts in London and New York for report and valuation.

The following report, dated November 9, 1905, was received from Messrs. Figgis & Company, London :—

'We are favoured with yours of October 18, and samples of India rubber, for which we are obliged.

'A. is nice-quality biscuit, well prepared, but a little damp, and immature ; value, about 5*s.*

'B. similar to above, but darker and containing more moisture ; value, about 4*s.* 6*d.*

'C. is good black scrap, very slightly barky, dry, and in good condition ; value, about 3*s.* 9*d.* to 4*s.*

'The first two samples are rather immature and soft, which, possibly, can be avoided by more careful curing of the rubber. Both contain too much moisture, B. especially so, and they should be better dried. This may be possible by preparing the biscuits a little thinner than the samples you have sent. All three qualities will sell very well.'

Messrs. Hecht, Levis & Kahn, London, report on similar samples, under date of November 8, 1905, as follows :—

'We have your favour of October 18, and also samples advised therein. These samples show rubber of very nice quality, which will be readily saleable in this market. Sample A. we should value to-day at 4*s.* 9*d.* to 5*s.* per lb.

'Sample B., which is somewhat porous and not so well cured, at 4*s.* 3*d.* to 4*s.* 6*d.*

'Sample C. appears to be a very good quality of scrap rubber. As the sample is so small, it is difficult to judge what quantity of bark and other foreign matter would be in the bulk, but we should estimate value at about 3*s.* 10*d.*

'With regard to the biscuit rubber, we may say that the thinner you can make the biscuits the better, especially as by making them thin, the rubber, as a rule, gets much better cured.'

In subsequent experiments the use of formalin in half the former strength was tried, but with similar unsatisfactory results. The latex was allowed to stand for five days, but the rubber did not agglutinate sufficiently to be handled, and mildew attacked the surface of the thick cream.

Much drier samples of a lighter colour have since been prepared, by not exceeding a thickness of about $\frac{1}{4}$ inch when moulding the rubber into biscuits or strips, and then subjecting these to pressure in a screw press. It is expected that these samples will command a higher value than those formerly sent.

TAPPING RESULTS.

The total yield from the nine trees was estimated to be 104·93 oz., or an average of 11·66 oz. per tree. This may be considered a good amount, as the yield of the six poor trees could not be estimated at more than 6·9 oz. per tree. Particulars about the different trees may be obtained by consulting the following table :—

No. of tree.	Height of tree.	Circumference		No. of V incisions.	Height of top incision.	Average yield of rubber per incision.	Yield of dried rubber.
		At base.	At highest incision.				
	Feet.	Feet.	Feet.		Feet.	Oz.	Oz.
1	49	5·50	4·00	53	11·75		40·00*
2	37	3·00	2·00	19	5·00	·55 for six trees.	41·40*
3	38	3·00	2·41	21	6·75		
4	25	2·00	1·75	16	6·50		
5	25	1·66	1·50	12	6·25		
6	29	2·33	1·83	17	6·00		
7	30	2·33	2·00	10	6·00		
8	43	3·50	2·50	19	11·50	·49	9·33†
9	38	3·50	2·58	19	11·50	·75	14·20†
Total		...	...	186	...	...	104·93

* Estimated yield for the respective trees.
† Actual yield for the respective trees.

TIME FOR TAPPING.

A first tapping was commenced in August and continued throughout September. A second in November. The rainy season was selected on account of the latex running more freely than in the dry season.

With the exception of tree No. 9, the tapping was done in the early mornings on alternate days, this method being adopted in view of the results obtained in experiments carried out in tapping Para rubber trees at the Botanic Gardens, Singapore. These show that morning and alternate day tappings have a distinct advantage over evening and daily tappings in the yield of rubber per tree. It has been observed in our subsequent experiments, that when a dozen double incisions were made in the space of about one hour on the same tree, the last made gave much less latex than the first. On another, but somewhat smaller tree, a total of fifty-three similar incisions were made, but with an interval of at least forty-eight hours between each series of five, and it was found that the flow of latex in the latter part of the tapping was not noticeably less, but was more liquid and probably contained a lower percentage of rubber. This decrease, in the percentage of rubber in the latex of the later tappings on the alternate system, appears to be more than counterbalanced by the larger flow.

In this connexion Mr. Derry in his 'Notes on tapping experiments with Para rubber trees,' recorded on p. 340 of the *Agricultural Bulletin* of the Straits and Federated Malay States for September 1904, states :—

'From a series of tests and measurements, I conclude there can be no doubt that the flow of latex depends entirely on the pressure of water (and the contraction and expansion of a tree during the course of a day is considerable). A tree of 3 feet girth at 3 feet from the ground, measuring exactly 3 feet at 6 a.m. would, by afternoon, according to the brightness of the day, contract to a maximum of $\frac{1}{2}$ inch, and by 6 p.m., or soon afterwards, expand to early morning measurement. Or, if a ligature be fixed tightly on a tree, it can be observed that in the early morning the ligature is fully stretched. By afternoon, if a bright warm day, it is quite slack or partly so, according to the day, and as the evening advances, it gradually braces up. On wet days the ligature is expanded to tension point, and the flow of latex is considerably increased, but contains a high percentage of water, as is seen by the excessive residuum when the latex has coagulated. In wet weather it seems best to tap some hours after a storm, and to get the best result from evening tappings, the work should be deferred as late in the day as possible.

On a dry hot day, the water contents of a tree may be considerably reduced by transpiration, and sometimes to such an extent as to cause, in some plants, a visible effect upon the foliage, owing to the rate of transpiration exceeding that of the intake of water at the roots. This may possibly cause a decreased liquidity and pressure in the fluids of the stem, to which it appears reasonable to attribute the differences in the flow of latex in morning and evening or daily and alternate day tappings.

In this direction an experiment was carried out with trees Nos. 8 and 9, which were selected on account of their uniformity in size, shape, vigour, and position, with the object of ascertaining whether a greater yield of rubber could be obtained by

tapping a tree at intervals of about forty-eight hours, than by completing the operations on one occasion. The results were as expected, the alternate system indicating a gain of 52 per cent. in dry rubber.

No. 9 was tapped with nineteen V incisions at one operation on the morning of November 2, and gave 9·33 oz. of dry rubber. No. 8 was tapped with an equal number of similar incisions, but made at different times, three incisions being made on the mornings of each of the dates November 4, 7, 11, 16, and four on November 18. The yield from this tree was 14·2 oz. of dry rubber.

TREES IN ST. LUCIA.

It is estimated that there are at present in the island between 300 and 400 Castilloa trees, the majority ranging in ages from five to twelve years, and in addition, about 700 plants have been distributed from the Botanic Station during the last four years. I have personally inspected some of the established trees, and information has also been kindly furnished by Messrs. G. S. Hudson and G. Barnard, on the condition of the trees on their respective estates, Errard and Parc.

On the Errard estate the largest tree is twelve years old, 70 feet high, and 5 feet 6 inches in girth, and the average measurements of a number of trees are reported as follows:—

Age twelve years, girth 4 feet; age eight years, girth 3 feet; girth measurements in each case being at 3 feet from the ground.

These are growing at an altitude of about 750 feet as shade trees in cacao fields on rich, well-drained, steep hillsides.

They are generally exposed to prevailing winds, being protected only by belts of forest that surround the larger cacao fields. They are, on the whole, healthy and vigorous, and seem to be quite suitable as a shade tree for cacao, particularly on rich soil, if any shade is needed.

In September 1905, twelve eight-year old, and five twelve-year old trees on this estate were partly tapped, with a total number of eighty V incisions. A total yield of $3\frac{3}{4}$ ℔. of biscuit and $\frac{1}{4}$ ℔. of scrap rubber was obtained. Mr. Hudson reports that, a few days after tapping, the trees seemed full of latex, and he estimates that a thorough tapping would yield from 1 ℔. to 2 ℔. of rubber per tree.

On this estate it has been observed that on poor, dry soil, the tops of the trees are apt to die back in dry seasons, and the growth is altogether less satisfactory, and therefore, on such soils they are unlikely to be useful as shade.

On the Parc estate a tree seven years old is 48 feet high, and 3 feet in girth; another is 36 feet high and 3 feet 10 inches in girth. The average measurements of a number of trees are:—

Age five years, height 25 feet 4 inches, girth 2 feet 4 inches.

Age seven years, height 39 feet 2 inches, girth 2 feet 11 inches; the girth in each being at 3 feet from the ground.

These trees are growing at distances varying from 40 to 60 feet apart in cacao fields, on flat, well-drained, and deep alluvial soil, at an altitude of about 700 feet, and are sheltered from strong winds by high ridges.

Mr. Barnard states that these trees have made very uniform growth and are vigorous and very healthy. They make fairly good shade trees for cacao, and no ill effects, which could be attributed to the presence of the rubber trees, have been noticed on the cacao.

There are also one or two other estates on which Castilloa is thriving under similar conditions.

The land most suitable for growing this rubber tree may be best described as 'cacao land.' The tree inhabits a warm humid climate and appears to be rarely found above an altitude of 1,500 feet. It requires deep rich soil, an average rainfall of not less than about 70 inches, but will not thrive in swampy land nor where there is not good drainage at its roots.

All these conditions of climate and soil exist in St. Lucia, and the result of local experiments in the cultivation and tapping of these trees appears to afford ample evidence of the success that is likely to attend their extended cultivation in this island. The best time to plant in St. Lucia is between the months of June and November, and every effort will be made by the Agricultural Department to meet demands for plants and seeds.

As a supplement to the above paper, the following extract is taken from a report to the Imperial Commissioner of Agriculture by the Agricultural Instructor, Mr. George S. Hudson, dated St. Lucia, October 13, 1905:—

'Mr. Moore spent a few days with me at Errard estate in the latter week of September, and kindly placed at my disposal the experience he has lately gained in experimenting with the extraction and preparation of rubber from *Castilloa elastica*. I have some hundred large trees of twelve and eight years of age planted amongst cacao. The latter average 3½ feet in circumference, and the former 4½ feet, at 3 feet from the ground. We made eighty V incisions on seventeen trees, the majority of which were eight years old, the yield of dry rubber thus obtained being 4 ℔., an average of ¾ oz. from each double incision,* which, so far as I can gather from the published Ceylon and Tobago reports, is in excess of what has hitherto been obtained at these places. I tested the trees a few days after this first tapping and found that the latex still flowed readily even in the immediate vicinity of the cuts, and I estimate that a thorough tapping (which I intend to undertake shortly) should yield 1½ ℔. to 2 ℔. per tree of pure rubber. I estimate the cost in labour of collecting and curing this rubber at about 1s. per ℔. The rubber thus prepared oxidizes to a dark brown on the surface, but the interior of the cured cakes is perfectly white, and I anticipate that the quality will be found high. I leave it to Mr. Moore to explain his method, and merely give the results here: but I may mention, as he was not present at the later stages of coagulation of the latex, that it 'creamed' six times, and produced white rubber

* Mr. Moore states that he thinks this estimate is too high, as it is unlikely that the rubber was quite dry when this estimate was made.

to the last. This I take to be due to the fact that I did not add fresh water or any chemical after each creaming. This process, however, is somewhat tedious, and I would suggest that if the Commissioner thinks favourably of Mr. Biffen's Centrifugal Extractor, and the Department would import one, I would be prepared to give it a fair trial on this estate. I was able to show the process of rubber coagulation to Messrs. Deacon, W. Malet-Paret, Dennehy and Ward, and hope to induce tapping of Castilloa trees on several estates possessing a few trees. It would certainly appear from these initial experiments that, apart from separate plantations, the question as to whether Castilloa should take the place of Immortel in cacao plantations is one demanding serious attention; and if the returns from my Castilloa trees (which are all planted amongst cacao) prove to be as good as I anticipate ($1\frac{1}{2}$ ℔. to 2 ℔. per tree at each thorough tapping), I should certainly decide to use Castilloa as a substitute for Immortel, and recommend others to do so.'

A further extract from a report of the Agricultural Instructor, dated St. Lucia, January 2, 1906, is as follows:—

'In continuance of my remarks in my last report on Castilloa as a shade tree for cacao, I find on going into the matter thoroughly, that planting Castilloa at 60 feet apart amongst cacao would be unobjectionable from the cacao grower's point of view, were it not that the return would be so small (twelve trees per acre, annual yield after eight years, 1 ℔. per tree, net value 4s. per ℔.) as hardly to repay the loss of nitrogen to the soil by the absence of Immortel shade trees.* On the other hand, if Castilloa trees were planted at 30 feet apart amongst cacao, the latter would subsequently suffer from over shading. Yet I am of the opinion that a return of £10 per acre after the eighth year from the rubber trees, would in many cases relegate cacao to the position of a 'catch crop' and more than compensate for loss on the cacao crop.'

* Mr. Moore states that he thinks that the question, as to whether the loss of nitrogen, due to the substitution of twelve Castilloa trees per acre as shade in a cacao field instead of Immortel, would be repaid by the rubber obtained, is at present one that can hardly be settled satisfactorily on a theoretical basis alone. He considers that it involves a number of other questions of a correlative nature and it would be inadvisable in the absence of more complete knowledge in support of the theory, to withhold, on these grounds, recommendations to plant Castilloa as shade for cacao.

COTTON INDUSTRY IN THE LEEWARD ISLANDS.

BY THE HON. FRANCIS WATTS, C.M.G., D.Sc., F.I.C., F.C.S.

Cotton growing has made such rapid progress within the last few years, and has become a factor of such importance to several of the islands, that it is desirable to record the various stages through which the industry has passed.

The first step in the present movement appears to have been taken in 1900, when a small plot of cotton was planted in the Experiment Station at Antigua. The seed was derived from an abandoned Experiment Station where, some six or seven years previously, the Botanical Department of Antigua had conducted experiments in cotton growing. No machinery existed whereby the cotton could be ginned, and little appears to have been done to ascertain the value and quality of the lint. The plants, however, grew so successfully as to lead to further experiments. (Report on Economic Experiments at Botanic Station, Antigua, 1900-1, p. 10.)

In consequence of the foregoing, experiments of a more definite character were undertaken in the following year (1901), at the Experiment Stations in Antigua and Montserrat. For these experiments, freshly imported seed of three varieties of Upland, and one variety of Sea Island cotton were used. The growth in both islands was satisfactory, though the largest returns were obtained at Montserrat. In this year, Messrs. Sendall and Wade planted two trial plots in Montserrat, each of one acre in extent, one at Dagenham, the other at Bethel.

By this time a small hand-power roller-gin had been provided at Antigua, so that it became possible to submit the products of the trial plots to more complete examination than before. Samples were submitted to the Manchester Chamber of Commerce for valuation. The Upland varieties were valued at from 4½*d.* to 6*d.* per ℔. The sample of Sea Island cotton from the Botanic Station at Montserrat was valued at 7½*d.* per ℔., and the remark was made that this 'might easily fetch considerably more money.' The sample of Sea Island cotton from Antigua was valued at 8½*d.*, with the remark that it was 'well thought of, but had not been prepared to the best advantage' (*Agricultural News*, Vol. I, pp. 163 and 195). From these experiments, it became evident that Sea Island cotton could be satisfactorily grown, and that this variety is the one to which attention should principally be directed. (See Reports on Botanic Stations, Antigua and Montserrat, 1901-2.)

These experiments, simple as they were, had an important bearing on subsequent events. They showed what kind of cotton could be expected to give the most useful results, and also gave general information as to the cultural operations that were necessary for its production. Attention was therefore now directed to cotton as a crop which would probably prove remunerative.

In the succeeding year (1902), cotton growing attracted increased attention. The present writer read a paper before

the Agricultural and Commercial Society of Antigua on August 1, reviewing the position and advocating the cultivation of the Sea Island variety (*Agricultural News*, Vol. I, pp. 153 and 169). As the outcome of this, fourteen experiment plots were laid out on various estates in Antigua, in addition to the experiments at the Botanic Station. Returns were obtained from nine estates and published in the Report of the Antigua Botanic and Experiment Stations, 1902-3. Although the yields were not very large, they were encouraging, and from this period may be dated the cultivation of Sea Island cotton in Antigua on a commercial scale.

In 1902, cotton planting was undertaken on a commercial scale by Messrs. Sendall and Wade who planted about 230 acres in St. Kitt's and about 100 acres in Montserrat. Cotton was also grown in Montserrat by Mrs. Howes on Trants' estate, while small experiment plots continued to be cultivated at the Botanic Station. In this year two experiment plots were laid out in Anguilla by Dr. Rat.

Cotton growing had now reached a stage when adequate machinery for the preparation of the lint became necessary Consequently, early in 1903, Messrs. Sendall and Wade established a ginnery containing two gins and a baling press, worked by steam power, at Spooner's in St. Kitt's, and a similar installation at Dagenham in Montserrat. During 1903, Mrs. Howes of Montserrat, obtained assistance from the then newly formed British Cotton-growing Association and started a small ginnery, also worked by steam power.

At the close of the year a ginnery containing three gins, driven by steam power, with a hand-baling press, was erected at Antigua and was ready for work in December. The greater part of the machinery was supplied by the British Cotton-growing Association. This was first used in ginning the crop of 1903-4.

As the result of these efforts, there appears to have been produced about 22,880 ℔. of lint in St. Kitt's and 27,600 ℔. in Montserrat, the Antigua product being insufficient to produce commercial shipments.

During the latter half of 1903, cotton planting was proceeded with in an energetic manner in most of the islands. In Antigua, about 500 acres were reported to have been planted, but owing to various causes, including drought and pests, much of this produced but poor returns. Some growers were, however, very successful, and it began to be clear that cotton growing, with knowledge and skill, would be a profitable industry for Antigua. (See report on cotton in Report on Botanic Station, 1903-4, p. 12.)

In St. Kitt's, about 350 acres were planted, while in Montserrat about 600 acres appear to have been put in. At the Dagenham ginnery in Montserrat, an oil engine replaced the steam engine for driving the machinery, and proved very satisfactory.

A small quantity of cotton was grown in Anguilla, which had to be sent to one of the neighbouring islands to be ginned.

The cultivation of cotton in Nevis, on a commercial scale, began in 1903, when about 400 acres were planted. In the early part of 1904, Mr. E. Y. Connell, with the assistance of the British Cotton-growing Association, erected a steam ginnery with three gins, and a hand-baling press.

The out-put of cotton for the crop of 1903-4 was as follows :—

Montserrat	...	...	...	70,000 ℔.
Nevis ...	...	..	...	28,449 ,,
Antigua	...	..	...	27,853 ,,
St. Kitt's	...	...	...	24,197 ,,
Anguilla	...	...	...	1,661 ,,

On the whole, the cotton thus produced was very favourably reported upon, and good prices, ranging about 1*s.* 1*d.* per ℔., were obtained.

During the period that the above-mentioned crops were being grown, the Hon. Sir Daniel Morris, K.C.M.G., accompanied by Mr. J. R. Bovell, F.L.S., F.C.S., paid a visit to the districts producing Sea Island cotton in the United States of America. Much useful information was thereby gained and disseminated amongst the cotton planters. One of the most useful features of the visit was the securing of a large supply of Sea Island cotton seed of a superior quality. This was extensively used by the planters, who put in cotton in the latter half of 1904, to be reaped in the early part of 1905. The result was an appreciable improvement in the quality of the cotton produced in these islands, in consequence of which, the attention of the fine spinners was directed to this source of supply of fine cotton. This seed was in great demand, and more could have been disposed of, if it could have been obtained. As it was, 11,114 ℔. of seed were distributed in the Leeward Islands.

In the planting season of 1904, considerable activity was displayed in all the islands, cotton receiving much more attention than formerly. The acreage planted in each island may be approximately stated as follows :—

St. Kitt's	1,050	acres.*	Anguilla	450	acres.
Nevis	1,000	,,	Antigua	400	,,
Montserrat	600	,,	Barbuda	60	,,

With this considerable increase in cultivation, additional attention was given to machinery, so that when ginning operations began at the end of 1904, or beginning of 1905, the position was as follows :—

At St. Kitt's, a new ginnery with two gins, driven by a Cundall oil engine, was established at Sandy Point. The ginnery at Spooner's had some time previously been equipped with a disintegrator for crushing seed, all the machinery being

* Partly as a 'catch crop' with sugar-cane.

still efficiently worked by steam power. A new ginnery with two gins driven by an aermotor was erected at Stone Fort. This also contains an appliance for crushing seed.

At Nevis, an oil engine was substituted for the steam engine at Mr. Connell's ginnery, and a small gin driven by horse gear was put up at Richmond Lodge.

At Montserrat, the machinery already installed was found sufficient, and no additions were made.

At Anguilla, two ginneries, both worked by oil engines, were established; the British Cotton-growing Association assisting in the erection of one of these, which contains two gins. The other contains one gin.

At Antigua, a Cundall oil engine was substituted for the steam engine for driving the gins, and a Christie and Norris disintegrator installed for crushing seed.

At Tortola, a gin driven by an aermotor was erected at the Botanic Station, the assistance of the British Cotton-growing Association being obtained for this.

The results justified this activity, for the shipments of 1905 have been as follows:—

Nevis	144,721	lb.
St. Kitt's	76,899	,,
Montserrat	70,723	,,
Antigua (including Barbuda) ...	54,016	,,
Anguilla	30,977	,,
Virgin Islands...	3,600	,,
	380,936	,,

The cotton thus produced was of superior quality to that previously grown, and realized good prices, averaging, probably, about 1*s.* 2*d.* per lb. Small quantities sold as high as 1*s.* 4*d.* per lb., while a large part of the crop sold at 1*s.* 3*d.*

In this season, extensive series of manurial experiments were conducted jointly by the Department of Agriculture and the planters. The results tend to show that, with cotton as a crop new to these islands, artificial manures are not yet necessary; but planters are advised that this condition may not hold good in the future. It is considered advisable for them to use their cotton seed as food for stock, or to apply it as manure, so as to avoid the loss of the valuable fertilizing constituents which it contains, it being believed that this course is best calculated to maintain the fertility of the cotton fields and obviate the necessity for the purchase of artificial manures.

The visit, during November 1904, of Mr. E. Lomas Oliver, on behalf of the British Cotton-growing Association, did much to stimulate interest in cotton growing, and to bring the growers and spinners into closer union, whereby each better understands the needs of the other. Mr. Oliver, accompanied by Sir Daniel Morris and the writer, visited Montserrat, Antigua, St. Kitt's, and Nevis. Opportunities were afforded of inspecting growing cotton at each place, while public meet-

ings were held in the Court House in each island, thus enabling Mr. Oliver to interchange views with the leading cotton growers.

Assured of a reasonable prospect of success, the planters showed a disposition to increase the extent of their cultivation, so that now (November 1905), the following approximate estimates of the acreage in the various islands may be made :—

Nevis	1,700 acres.	Antigua	600 acres.
Anguilla	1,000 „	Barbuda	70 „
Montserrat	800 „	Virgin Islands	40 „
St. Kitt's	800* „		

Two new ginneries, to be worked by oil engines, are being erected in Nevis to be ready for working early in 1906.

Owing to the uncertainties of a cotton crop it is impossible to state with any degree of precision what the output of the various islands is likely to be. There is reason, however, to look for a very considerable increase over the crop of 1905.

In Antigua and St. Kitt's, where the cultivation of sugar is still extensively carried on, cotton remains of secondary importance. In Montserrat, it bids fair to be of primary importance in a very short time. In Nevis, the cotton industry has effected a remarkable change and altered the whole aspect of affairs. Cotton growing is now the principal industry, and finds employment for a population which hitherto lived precariously. Nevis now enjoys a modest degree of prosperity, the cultivation of cotton most opportunely minimising the intensity of the struggle to exist upon a possibly decadent sugar industry.

The change effected in Anguilla is perhaps even more remarkable than in Nevis. The exports for many years have been very small, amounting in value to only a few hundred pounds, and agriculture was at a very low ebb. As the result of its last crop, Anguilla shipped cotton to the value of over £1,500, while, should no disaster overtake the crop now growing, the exports in 1906 should have a value of several thousands of pounds. With good fortune, it is possible they may even reach a value of some £7,000 to £10,000. If anything approaching this is achieved, the change will be little short of marvellous.

Insect and fungoid pests have given a considerable amount of trouble, and call for much active work on the part of the planters, and of the officers of the Department of Agriculture.

The cotton worm (the larva of *Aletia argillacea*) has appeared as a serious pest in all the islands, and at times is present in enormous numbers. It can be combated by the prompt and energetic use of Paris green: but, unless the greatest care is exercised, this pest may get the upper hand, whole fields being stripped of their leaves and injured.

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* Six hundred acres of which are estimated as 'catch crop' with sugar-cane.

In 1903, a disease, now known under the name of 'leaf-blister mite,' due to the presence of a mite (*Eriophyes gossypii*), was first observed at Montserrat (*Agricultural News*, Vol. II, p. 309). It has subsequently been found practically throughout the Leeward Islands. Unless very energetic measures are taken for its control, it becomes a serious pest, and may entirely ruin the cotton fields. The retention of old cotton bushes being the chief means by which it is disseminated, the Department of Agriculture strongly advises the destruction of all old cotton bushes immediately the crop is picked.

In 1904, a disease known as 'black-boll' was first observed in Montserrat, in some parts of which it has occasioned considerable damage. It has since been observed in other parts of the Leeward Islands, but so far, no very disastrous attack has been reported outside of Montserrat. This disease is obscure in its origin, and no definite remedies have yet been suggested. (*West Indian Bulletin*, Vol. VI, p. 120.)

Various pests and diseases, at present of less importance, are to be met with in the cotton fields, rendering constant vigilance necessary both on the part of the Department of Agriculture and of the planters. Constant attention will be necessary in order to observe and study the various pests, and to devise means of keeping them in check.

Amongst the lines of work for the future, there remains the important duty of seed selection, with the object of improving the quality of cotton grown in these islands. This line of work will probably become more and more important as the industry develops, and will demand men, time, patience, and money for its prosecution.

The development of the cotton industry in the Leeward Islands, as briefly outlined in the foregoing sketch, has been phenominally rapid, and is of considerable importance in the economy of these islands. The vigour with which the industry has been taken up effectually disposed of the reproach, often levelled against the West Indian planters, that they are averse to taking up new ventures, and are slow to grasp opportunities of improving their positions. While the planters have, in this instance, been keen to avail themselves of the opportunities within their reach, it is but just to lay stress upon the fact that, but for the existence of a Department of Agriculture to foster the industry, and of the British Cotton-growing Association to assist in providing machinery and in dealing with the cotton when ready for market, not only would there have been a very much slower development, but it is extremely doubtful if there would have been any cotton industry at all.

ON ASCERTAINING THE STRENGTH OF CONCENTRATED LIME JUICE BY MEANS OF A HYDROMETER.*

BY THE HON. FRANCIS WATTS, C.M.G., D.Sc., F.I.C., F.C.S.

In a previous paper submitted to the Agricultural Society of Dominica, and published in the *West Indian Bulletin* (Vol. V, pp. 236-40), I made suggestions for the use of a hydrometer for ascertaining approximately the strength of lime juice. In that paper it is stated that the hydrometer and the table may be used to ascertain approximately the strength of concentrated lime juice, by carefully diluting the concentrated juice with water to ten times its volume. This may conveniently be done by accurately filling with concentrated juice a flask holding exactly 100 c.c., then transferring this juice to a flask holding 1,000 c.c. (1 litre), and filling up the 1,000 c.c. flask with water. The small flask must be carefully washed out with the water used for diluting, so that all the concentrated juice measured in the 100 c.c. flask is transferred to the large flask.

The hydrometer is floated in the diluted juice, the reading noted and multiplied by ten to give the strength of the concentrated juice.

Thus:—If the hydrometer floats at 1,029 in the diluted juice, the strength is, approximately, 11·04 oz. per gallon, or, in the concentrated juice, 110·4 oz. per gallon.

It should be pointed out that with anything but pure solutions the results are only approximately correct, but it is believed that they will be sufficiently accurate to be useful in ordinary estate practice.

Since the above was written, I have had an opportunity of examining several samples of concentrated juice by the method stated, and of comparing the results with those obtained by titrating with alkali. It must be remembered that even titration by means of alkali does not accurately determine the true citric acid, but only the free acidity, which may be due in part to acids other than citric.

The results were as follows:—

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* This paper was communicated to the Dominica Agricultural Society and published in the *Official Gazette*, February 3, 1906, for general information.

Mark.	Sp. Gr. $\frac{30^\circ \text{ C.}}{16{\cdot}6^\circ \text{ C.}}$ Reading of instrument in diluted solutions.	Oz. of citric acid per gallon by table, assuming 82 per cent.*	Oz. of citric acid per gallon by titration with Alkali.	Difference.
Layou Park	1·0309	117·1	124·54	– 7·4
St. Aroment	1·0321	121·5	118·7	+ 2·8
La Haut	1·0234	90·1	89·6	+ 0·5
Hampstead	1·0326	123·3	116·9	+ 6·4
Corlet	1·0326	123·3	108·2	+15·1
Pointe Mulâtre	1·0255	97·6	99·0	– 1·4
Lisdara	1·0308	116·8	109·3	+ 7·5
Bagatelle...	1·0304	115·4	109·3	+ 6·1
Hampstead B.	1·0268	102·3	97·7	+ 4·6
„ C.	1·0257	98·4	95·9	+ 2·5
„ D.	1·0275	104·9	104·0	+ 0·9
„ E.	1·0245	94·0	92·7	+ 1·3
„ F.	1·0259	99·0	96·8	+ 2·2
„ G.	1·0378	142·0	138·0	+ 4·0

The above will show what approach to accuracy may be expected in the use of the hydrometer with concentrated juice.

With two exceptions, those of Layou Park and Pointe Mulâtre, the indications of the hydrometer are higher than the results obtained by titration, the difference being variable and ranging from about 1 oz. up to 6 or 7 oz.

The case of the sample from Corlet appears to be exceptional, and I anticipate that inquiries will show that this was not a normal sample of juice.

* An arbitrary assumption was made in constructing the table (*West Indian Bulletin*, Vol. V, pp. 238-40), namely, that the impurities or substances other than citric acid, might be approximately allowed for by assuming that the citric acid present in the juice is 82 per cent. of the amount which would be indicated in pure citric acid solutions.

From this it appears that by means of the hydrometer and the table a planter can ascertain approximately the strength of the concentrated juice which he is producing, and can introduce into his work a measure of control which has hitherto been wanting.

What is necessary now, is that the planters shall insist in the use of the citrometer in determining the point to which juice is to be concentrated, and then that each lot of concentrated juice, after diluting as described above, shall be tested by means of the hydrometer. The indications of the hydrometer should then be compared with those of the citrometer ascertained during the process of concentration. Should the hydrometer indications be too high, the workman should be instructed to boil to a lower degree on the citrometer. Should a higher concentration be wanted he should be instructed to boil to a higher degree accordingly.

Very little care and observation on the part of the planter will enable him to concentrate to any point which he may fix upon as most desirable.

My observations led me to conclude that in the past there was a tendency in Dominica to concentrate to too high a degree. This was due to the impression that by concentrating, say, 12 to 1, instead of 8 to 1, there is a great saving of freight and packages. This is true in some degree, but high concentration is accompanied by destruction of citric acid. If the freight and packages of a cask of concentrated juice cost, say, £2, and the juice be worth, say, £15, then a saving of one-third of the freight and packages will effect a saving of 13*s.* 4*d.*; a loss of 5 per cent. of acid will entail a loss of 15s., and a loss of 10 to 15 per cent. of acid may easily occur from over concentration, entailing a loss of 30*s.* to 45*s.*

Moreover, I am informed that the purchaser of concentrated juice prefers to have his supplies concentrated to a moderate degree, concentration from 95 to 100 oz. being preferred to that of 130 to 140 oz.

I can only repeat the advice which I have already given. (See *West Indian Bulletin*, Vol. II, p. 309). 'Carry on the concentration until the citrometer, when immersed in the juice at boiling temperature, shows a density of 60°.' The concentrated juice thus obtained will contain about 100 oz. of citric acid per gallon. If on testing the resultant juice with the hydrometer in the manner described, it is found to be too highly concentrated, then a lower degree on the citrometer must be taken as the point to which to concentrate. There will be variations in each district, so that the correct point can only be found by experiment.

With the combined use of the citrometer and the hydrometer, the planters have the means of producing concentrated juice of a uniform quality, and of approximately learning its strength.

I have recently adopted a method in examining concentrated lime juice which gives interesting comparative results.

If a mixture be made by diluting 100 c.c. of concentrated juice with water to 1 litre, and poured into a tall graduated cylinder, to stand over night, it is found that the liquid deposits a bulky black sediment, the volume of which may be noted after standing about twenty hours.

In the samples above reported on, the volumes observed were :—

Mark.	Volume of sediment.	Mark.	Volume of sediment.
St. Aroment ...	95 c.c.	Hampstead B. ..	30 c.c.
La Haut	75 ,,	,, C.	40 ,,
Hampstead ...	40 ,,	,, D. ...	20 ,,
Corlet	85 ,,	,, E. ...	40 ,,
Pointe Mulâtre ...	50 ,,	,, F. ...	40 ,,
Lisdara	55 ,,	,, G. ...	65 ,,

The amount of sediment in several of the samples from Hampstead is particularly small.

NOTES ON WEST INDIAN INSECTS.

Under the title of 'Notes on the Insects of Barbados, St. Vincent, the Grenadines, and Grenada,'* Mr. Austin H. Clark, Boston, Mass., published the following in *Psyche* for December 1904:—

The island of Barbados is unique among the islands of the Lesser Antilles in being truly oceanic in the sense of not having had any land connexion since the introduction of its present—comparatively speaking—meagre fauna. It differs from all the other islands in being flat, and superficially of coral formation, and is separated from them by soundings of between 1,000 and 1,500 fathoms, while the nearest (St. Vincent, and St. Lucia) are about 100 miles away. The fauna is wholly made up of common and generally distributed West Indian types, except where, as in the case of some of the birds, prolonged isolation has given rise to forms different from, though closely related to, others on neighbouring islands. In the case of the insects, they have been brought there either by winds or on floating wood, etc. Of course many have been accidentally introduced by man. There is no other island in the world so highly cultivated as Barbados, the forest having everywhere given place to the cane field; and this doubtless accounts for the paucity of its lepidopterous fauna to some extent.

The economic entomolgy of this and the other West India Islands has received considerable attention from the Imperial Department of Agriculture for the West Indies, and is dealt with in their periodicals, the *West Indian Bulletin* and the *Agricultural News*, both published at Bridgetown, Barbados.

The butterflies observed here were very few, both in species and in numbers, although I have visited the island at all seasons of the year. The commonest is *Callidryas eubule*. Others frequently seen are *Agraulis vanillae*, *Junonia coenia*, *Colaenis julia*, *Eurema lisa* (?), *E. elathea* (?), several *Lycaenids*, and a number of skippers. *Pontia monuste* and *Anosia plexippus* are occasionally met with.

St. Vincent is high and rugged, with a large area of forest; in fact only the lower parts of the river valleys have been cleared of trees. In the woods along the mountain paths, *Papilio polydamus* is very common, the larvae feeding on various species of wild *Aristolochia*. This species on St. Vincent appears to be above the average in size, with more yellow on the wings than in specimens from other localities. It is very abundant, and is sometimes found on the lower levels. I was surprised to find *Dione juno* common in the St. Vincent woods, taking the place of *Agraulis vanillae* of the lowlands. There is a very large, brilliant blue *Thecla* common in the highlands, and on one of the mountain ridges I obtained a freshly emerged specimen of *Rothschildia splendens*. On the

* These notes were made during a recent visit to these islands, beginning in July 1903 and ending in September 1904.

lower lands I found *Colaenis julia*, *Callidryas eubule*, *Agraulis vanillae*, *Eurema lisa*, *E. elathea*, *E. albula*, *Eudamus proteus*, and others of that group, various *Lycaenas* (including *Hemiargus hanno*) and a number of skippers common. *Pontia monuste* and *Anosia plexippus* occurred, but were not abundant; *Anartia jatrophae* was common about Kingstown, *Junonia coenia* was numerous in all the hotter and more desolate districts, and I saw three specimens of *Hypolimnas missippus*, one (a female) on November 6, 1903, another (also a female) on November 9, and a male on November 10. The first was on Kingstown Hill, and the other two in the Botanic Garden. This insect is rather rare on St. Vincent. The protective coloration of the female is here of not the slightest use, as there is no other butterfly anything like it, and this may account for its not gaining a foothold in these islands.

On October 2, 1903, I ascended the Soufriere, which very recently (1902-3) has been in active eruption. The vegetation on the volcano, and all about it, in fact over almost the entire northern third of the island, has been entirely destroyed: the district now being merely a desert of light-brown ash and scoria. About the base and up the sides of the mountain, the Guinea grass has begun to grow again, and farther down there are large numbers of castor oil plants. About one-fourth of the way up from the leeward side there is a patch of bananas, and by the side of it a patch of sugar-cane which have come up through the thick covering of ejecta, and mark the site of what was once somebody's garden. They are quite conspicuous, being the only signs of plants of any size on that part of the mountain.

As one looks from the crater of the volcano down on the devastated Carib country toward Georgetown, the thin covering of Guinea grass gives the landscape a fresh, green appearance, and it is hard to realize that not long ago in this very district two thousand lives were lost by an outburst from this mountain. Some mosses and an occasional fern may be found now in sheltered spots inside the 'new crater' which broke out in eruption in 1812.

Insects of various kinds are very common all the way to the summit, being rendered especially conspicuous by the lack of vegetation. Of butterflies, *Vanessa cardui* was almost the only kind seen, but this was very abundant, collecting on the bits of chewed sugar-cane and slivers of cane rind thrown down by the porters of parties which had recently made the ascent. These butterflies were found even on the rim of the crater; and their occurrence was particularly noticeable, as I have never seen the species at any other point on St. Vincent, nor on any other of the West India Islands (including Trinidad) although very likely it is found occasionally. I never saw it in Venezuela, although in parts of that country the conditions are somewhat like those existing to-day in the northern part of St. Vincent. One example of *Callidryas eubule* was met with near the summit, flying before the strong north-east wind, and near the same place I found a dead skipper. Most of the insects seen were Hemiptera, the commonest being the black and red

cotton stainer.* There were also many of the yellow-brown wasps (*Vespa?*) known locally as 'Jack Spaniards.'** About the rim of the crater, more especially along the southern side, there were hundreds of dead insects (mostly Hemiptera) which had apparently been killed by the sulphurous fumes which are continually pouring out.

As a whole, St. Vincent is rich in insects when compared with Barbados, although there do not appear to be many moths. I found *Utetheisa* abundant, as on all the islands I visited, but only saw one Noctuid. The absence of the Heliconidae and other similar families is noticeable, as one would think that the hot and damp valleys of this island would offer special inducements to them; and such a great number is found in Trinidad that it is rather strange none have strayed up here, or been accidentally introduced. The mole crickets (of which there are two species here) are a serious menace to agriculture, being exceedingly abundant, probably as a result of the introduction of the mungoose, which has killed off a large ground lizard which is said to have fed on them.

The screw worm fly (*Compsomyia*) occurs, but is not very common. I only observed it once. On the neighbouring island of St. Lucia it is numerous, and a great pest to the stock raiser. It is locally supposed to have been brought into that island by ships carrying mules from the Southern States to South Africa.

A brilliant steel-blue mosquito, peculiar to St. Vincent, is abundant in the forests, being found everywhere, but I never met with it in the lower altitudes.†

On the Grenadines, the lowland butterflies of St. Vincent are common; on Bequia and southward *Cystineura hypermnestra* is abundant in the dry woods, and on Canouan we first meet with *Phoebis argante*, which is common from that island to the continent of South America. *Pontia monuste* is the commonest butterfly of the Grenadines, although not at all abundant on St. Vincent. There are no *Papilios*, and the large blue *Thecla* and *Dione juno* do not occur, although the latter reappears on Grenada. The 'Jack Spaniard,' so abundant on Barbados and St. Vincent, building its nest everywhere under the eaves of houses, under the sills of windows, about the mouths of caves, or under the branches of trees, does not occur on Union Island, although it is very common on Mayreau and the northern Grenadines. The islands to the south of Union are free from this species also, but another wasp, a small black insect with white abdominal bands, known locally as the 'maribunta,'‡ is common on Grenada; it builds a large nest, usually rather high up in the trees.

* *Dysdercus annuliger.*—[Ed. *W.I.B.*]

** Several species of *Polistes* common in the West Indies are known as 'Jack Spaniards.' The one referred to here is probably *Polistes annularis.*—[Ed. *W.I.B.*]

† The brilliant steel-blue mosquito mentioned here is probably *Haemagogus cyaneus*, Fabr., which Theobald (*Monograph of the Culicidae of the World* Vol. II, p. 240) states is found in St. Vincent and South America. [Ed. *W.I.B.*]

‡ The common 'maribunta' of Grenada is *Polybia occidentalis.*—Ed. *W.I.B.*]

Mosquitos are exceedingly abundant on the Grenadines, especially in the lowlands of Carriacou; and unless a person travels with a net, sleep is almost impossible. They appear during the wet season, from June to November.

The parasol ant or 'gros-tête' is numerous on Carriacou, where it was probably introduced from Trinidad by small trading boats plying between the two islands, as it does not occur on the other Grenadines, nor on Grenada. This insect is a great pest, making it impossible to raise roses and a number of garden vegetables and other plants. It is very fond of the flowers of the red hibiscus.*

On Carriacou also there is a large milleped, locally called the 'congeree,' which appears here to have reached the northern limit of its distribution. It is very common on the higher lands, and a banana or mango skin thrown down anywhere soon becomes a mass of them.

The butterflies noticed on Grenada were the same as those on St. Vincent, with the addition of the two species (*Cystineura hypermnestra* and *Phoebis argante*) which do not extend farther than the Grenadines, and also *Historis odius* and *Avartia amathea*. *Papilio polydamus* and the large blue *Thecla* of St. Vincent are lacking. *Erebus odora* and *Herse cingulata*† are common here, and on Carriacou, and very likely on St. Vincent as well, although I did not find them on that island.

The object of my trip to these islands was to make a study of the birds, and I unfortunately found it impossible to bring back a collection of insects; but I am sure that this region, where the South American fauna meets the West Indian, would yield most interesting results to the student of geographical distribution in insects, as it has in regard to its birds and mammals; besides which a host of new forms would be brought to light, as shown by the results of collections which have been made on St. Vincent and on Union Island.

The following information concerning the butterflies of Barbados has been forwarded by his Excellency the Governor, Sir Gilbert T. Carter, K.C.M.G., in a letter to the Imperial Commissioner of Agriculture.

I have looked over Mr. Clark's notes in regard to Barbados. I think he is right in saying that there is a paucity of butterflies in this island. The only insect I have found common is that which Mr. Clark names *Junonia coenia* but which is really *J. genoveva*. I have looked very diligently, but have not seen one single specimen of *J. coenia*, which I know well, it having been very common in the Bahamas.

Catopsilia eubule (not *Callidryas*) is fairly common, and so is *Dione vanillae* (not *Agraulis*); but in no part of the island have I met '*Eurema*' (*Terias*) *lisa*, or *T. elathea* though I know both species well. I have only observed two species of

* The 'parasol ant' or 'gros-tête' is *Atta cephalotes*.—[Ed. *W.I.B.*]

† *Herse cingulata* mentioned here is *Protoparce cingulata* mentioned on p. 56.—[Ed. *W.I.B.*]

Lycaenidae, and five species of Hesperidae, and, so far, have not seen '*Pontia*' (*Pieris*) *monuste* at all.

Anosia plexippus, which is a very cosmopolitan insect is not very common here so far as my experience goes. Mr. Clark does not mention the striking and peculiar *Hypolimnas misippus* which is found here, but apparently not near Bridgetown. I have only seen one specimen, a female, which radically differs from the male, but my son saw several males on the top of Chalky Mount. I have never met with *Colaenis julia* in Barbados, though the caterpillar feeds on the Passion flower, like its near ally *Dione vanillae*.

I dare say if one could spend the month of August about Turner's Hall Wood and visit some of the gullies in the neighbourhood of the Scotland district, one would do better.

I regard *Junonia genoveva* as the commonest butterfly here and next to that *Catopsilia eubule*. Mr. Clark does not mention *Papilio polydamas* which evidently breeds in the island, but is not very common, probably because *Aristolochia* does not appear to be a common plant here. I have seen several specimens, but none near town.

NOTES ON WEST INDIAN ORTHOPTERA.

The following notes on a small collection of Orthoptera from the Lesser Antilles, with the description of a new species of *Orphulella*, by Mr. James A. G. Rehn, appeared in the *Entomological News* for June 1905 :—

The collection from which the following notes were made was transmitted to the author by Mr. Henry A. Ballou, Entomologist of the Imperial Department of Agriculture for the British West Indies. The bulk of the material was presented to the Academy of Natural Sciences of Philadelphia, a small number of uniques and species confused under one number being returned to the Department.

With few exceptions the following records are the first from the islands represented, several South American forms being here recorded from the West Indies for the first.

On comparison with the lists of St. Vincent and Grenada Orthoptera published by Brunner and Redtenbacher,* the number of species is found to be much less as the material is much less extensive, twenty-eight in number, while the St. Vincent and Grenada papers list eighty-two, but of the twenty-eight forms here treated, thirteen are not contained in the two previous papers.

Probably the most striking fact noticed in studying this collection is that regarding the distribution of the two species of *Orphulella* here treated. The widely distributed *O. punctata* is represented by specimens from Dominica and St. Lucia, having also been recorded from Grenada, St. Vincent, and Trinidad, while on Barbados it is apparently replaced by a quite distinct species, which, judging from the amount of

* *Proc. Zool. Soc. Lond.*, 1892, pp. 196-221 ; 1893, pp. 599-611.

material examined, is as abundant as *O. punctata* is in the localities where found.

Family FORFICULIDAE.

ANISOLABIS, Fieber.

ANISOLABIS MARITIMA (Gené).

Barbados. September 13, 1901. (In sea-weed ; H. M. Lefroy.) [No. G. 363.] Five specimens ranging in size from small immature individuals to adults.

This species was taken in October under dead wood in St. Vincent.

ANISOLABIS JANEIRENSIS (Dohrn).

1864. *F[orcinella] Janeirensis*, Dohrn : *Entom. Zeit.* Stettin, xxv, p. 285 [Rio de Janeiro, Brazil.]

Barbados. February 13, 1902. [No. 383.] One broken specimen. August 12, 1903. (Dr. Deane.) [No. 529.] One specimen. September 10, 1903. (H. A. Ballou.) One specimen.

Dominica. April 5, 1902. (Rotten wood.) One specimen.

This species has been recorded from St. Vincent, taken in January and October, under wood and leaves, and in fruit.

One specimen examined (September 10, 1903) has the tegmina decidely elongate and lateral, instead of broad and separated mesad by a slight space. This may be due to the specimen not having quite reached the imago state.

Family BLATTIDAE.

ISCHNOPTERA, Burmeister.

ISCHNOPTERA OCCIDENTALIS, Saussure.

1862. *I[schnoptera] occidentalis*, Saussure, *Revue et Magasin de Zoologie*, 2e ser., xiv, p. 170. [New Orleans.*]

Barbados. July 10, 1903. (H. A. Ballou.) [No. 213.] Three specimens.

Dominica. (H. M. Lefroy.) [No. G. 213.] One specimen.

This species has previously been recorded from Grenada, San Domingo, Mexico, Peru, and the type locality.

BLATTELLA, Caudell.

BLATTELLA SUPELLECTILIUM (Serville).

Barbados. November 5, 1901 (one). (H. M. Lefroy.) [No. G. 107.] Two males. Bay Mansion. July 1903. (H. A. Ballou.) [No. 560.] One female.

This species has previously been recorded in America from southern Florida, Cuba, San Domingo, Jamaica, Porto Rico, and Brazil.

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* The original description simply gives 'Nova' as the locality, but in the Mèmoirs (*Mém. l'hist. Nat. Mexiq.*, IV, p. 88) the locality New Orleans is indicated for the single specimen described.

BLATTELLA CONSPERSA (Brunner).

1865. *Ph[yllodromia] conspersa*. Brunner: *Nouv. Syst. Blatt.*, p. 106. [Brazil.]

Barbados. [No. G. 408.] One male.

This specimen agrees very well with the original description of this species, except that the lines on the pronotum are not apparent, only small spots being present. The great number of fine blackish dots sprinkled over the tegmina appears to be diagnostic of the species.

CERATINOPTERA, Brunner.

1865. *Ceratinoptera*, Brunner: *Nouv. Syst. Blatt.*, pp. 46, 75. Included *C. diaphana* (Fabricius), *picta*, *castanea*, and *peruviana*, Brunner, *poeyi* and *porcellana*, Saussure. Of these *poeyi* and *porcellana* have been removed to *Plectoptera*, and *picta* has been selected as the type by Kirby.*

CERATINOPTERA DIAPHANA (Fabricius).

1793. [*Blatta*] *diaphana*, Fabricius; *Ent. Syst.*, ii, p. 11 [Islands of equatorial America.]

Barbados. Easy Hall. September 24, 1902. (H. M. Lefroy.) [No. 560.] One female.

This species has previously been recorded from Cuba, Porto Rico, St. Thomas, and Bermuda.

PERIPLANETA, Burmeister.

PERIPLANETA AMERICANA (Linnaeus).

Barbados. June 1901 and October 18, 1902. [No. 163.] Three specimens.

PERIPLANETA AUSTRALASIAE (Fabricius).

Barbados. February 12, July and December, 1903. [No. 163.] Three specimens.

CHORISONEURA, Brunner.

CHORISONEURA MYSTECA (Saussure)?

1862. *Bl[atta] mysteca*, Saussure: *Revue et Magasin de Zoologie*, 2e ser., xiv, p. 167. [Tropical Mexico.]

Barbados. October 1902. (Miss Field.) [No. 408.] One specimen.

This individual is referred to *mysteca* with some doubt. This species has been recorded from Grenada, as well as Bogota and several localities in Guatemala and Mexico.

LEUCOPHAEA, Brunner.

LEUCOPHAEA MADERAE (Fabricius).

Barbados. December 30, 1902, and September 26, 1902. [No. 108.] Three specimens.

This widely distributed tropical species has previously been recorded from St. Vincent.

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* A Synonym. *Catal. Orth.*, i, p. 98, 1904.

Pycnoscelus, Scudder.

PYCNOSCELUS SURINAMENSIS (Linnaeus).

Barbados. February, 1900. (H. M. Lefroy, in part. [Nos. G. 20 and G. 153.] Four specimens.

One individual (G. 153) is very pale and considerably shrivelled, a condition probably due to it having been captured when freshly transformed into the condition of the imago.

This tropical and subtropical species has been taken in Grenada and St. Vincent.

Panchlora, Burmeister.

PANCHLORA VIRESCENS (Thunberg).

'*Blatta virescens*, Thunberg; *Mém. Acad. Sci.*, St. Petersb., x, p. 278.'

Montserrat. January, 1904. (H. A. Ballou.) [No. 153.] One female.

This species has previously been recorded from Cuba, Porto Rico, Mexico, Cayenne, and Brazil, and questionably from Costa Rica.

Family MANTIDAE.

Musonia, Stal.

MUSONIA SURINAMA (Saussure).

Barbados. Bay Mansion. December, 1903. [No. 102.] One male, one female. November 7, 1903. (H. A. Ballou.) [No. 600.] One male. (H. M. Lefroy.) [No. G. 102.] Two males.

This species has previously been recorded from Grenada, St. Vincent, Trinidad, Surinam, and Venezuela.

Parastagmatoptera, Saussure.

1871. *Parastagmatoptera*, Saussure; *Mém. l'Hist. Nat. Mexiq.*, ii, pt. I, p. 83.

Type: *Mantis flavoguttata*, Serville.

PARASTAGMATOPTERA LOBIPES, Redtenbacher.

1892. *P[arastagmatoptera] lobipes*, Redtenbacher: *Proc. Zool. Soc., Lond.*, 1892, p. 206, pl. xv, fig. 8. [South end, St. Vincent.]

St. Vincent. August 30, 1902. (T. W. Campbell.) [No. G. 453.] One female.

This species was originally described from St. Vincent, and has since been recorded from Grenada.

Family PHASMIDAE.

Clonistria, Stal.

CLONISTRIA LINEARIS (Drury)?

St. Lucia, July, 1904. (H. A. Ballou.) [No. 622.] One male.

This species has been recorded from St. Vincent and Grenada, and the specimen listed above is placed here with a query, as true *linearis* (from Antigua) was very imperfectly described.

Calynda, Stal.

calynda keratosqueleton (Olivier).

1762. *Mantis keratosqueleton*, Olivier; *Encyc. Method. Ins.*, vii, p. 639. [Based on Stoll; Surinam.]

Barbados. September and October, 1902. [No. 623.] Two females.

This species has never before been recorded definitely from any one of the West Indies, several authors having credited it to the islands as a whole. A closely allied form, *C. cyphus* (Westwood) has been recorded from St. Vincent and Grenada. but in the absence of a description of the female sex of that species, and the apparently close relationship to Stoll's figure.* I prefer to use tentatively a name based on the same sex as the material in hand.

Family ACRIDIDAE.

Orphulella, Giglio-Tos.

orphulella punctata (De Geer).

St. Lucia. (No. 440.) One male, one female, one nymph.

Dominica. Middleham. November 25, 1891. (W. R. Elliot.) [No. 319.] one female.

Not separable from specimens from St. Vincent, Vera Cruz, and Costa Rica. The species has previously been recorded from Grenada and St. Vincent, in the Lesser Antilles, as well as from Trinidad.

orphulella balloui, n. sp.

Types: Male and female; Bay estate, Barbados, West Indies, September 9, 1902 (male) and September 30, 1902 (female). (H. M. Lefroy.) [A.N.S. Phila.]

Allied to *O. punctata* (DeGeer) but differing in the more slender form, the more retreating face, the narrower excavation of the fastigium, the longer eye, the narrower costal expansion of the tegmina and the much more slender caudal femora.

Size medium; form elongate, slender. Head with the occiput and vertex hardly rounded, the interspace between the eyes slightly less than the greatest width of the fastigium; fastigium acute in both sexes, the margins raised and cingulate. excavation limited to a narrow depression caudad of the margins in the female, the greater portion of the dorsal aspect of the fastigium depressed in the male and without any very distinct excavation; lateral foveolae elongate trigonal; frontal costa strongly constricted dorsad, regularly and gradually expanding ventrad; latera ocelli rather large, placed by the eye at the ventro-caudal angle of the lateral foveola; eye acute ovate, the apex directed dorso-cephalad, length over half again that of the infra-ocular portion of the genae: antennae depressed, subensiform, slightly shorter than the head and pronotum together. Pronotum slightly less than twice as long as the greatest dorsal width, slightly tectate, median and lateral carinae distinct, the lateral parallel on about the

Natuurl Afbeeld, Besch. Spooken, pl. xv, fig. 57.

cephalic half, slightly and gradually diverging on the caudal half; cephalic margin subtruncate, caudal margin obtuse-angulate: metazona slightly shorter than the prozona; lateral lobes with the ventro-caudal angle rectangulate. Tegmina elongate, considerably exceeding the apex of the abdomen and slightly exceeding the femora: apex rounded, costal expansion low. Interspace between the mesosternal lobes very distinctly (male) or slightly (female) longitudinal: interspace between the metasternal lobes very narrow and strongly longitudinal in the female; the lobes contiguous in the male. Cephalic and median limbs little inflated. Caudal femora slender, over four times as long as the greatest width, which is in the basal third, genicular region very slightly arched, lobes narrowly rounded; caudal tibiae with eleven spines on the external and twelve on the internal margins.

General colour varying from wood-brown to russet, overlaid with the usual markings found in the brown phase of species of the genus; the male type having the base colour buff on the head and pronotum. Postocular bars and rather weak longitudinal occipital bars bistre; eyes raw umber.

Pronotum with the lateral lobes marked dorsad with bistre in the male, all except a distinct bar of buff on the ventral portion of the lateral lobes being obscured. Tegmina of the general colour, the anal areas lighter than discoidal in the male, maculations exceedingly faint in the female, and practically absent in the male. Caudal femora with the genicular arches burnt umber; ventral surface and the tips of the spines on the tibiae bistre.

	male.	*female.*
Length of body	15·0 mm.	21·5 mm.
Length of pronotum	3·0 „	4·4 „
Greatest dorsal width of pronotum	1·9 „	2·9 „
Length of tegmen	14·0 „	17·5 „
Length of caudal femur	10·0 „	12·0 „

A series of twenty-one Barbados specimens has been examined in addition to the types, taken in the months of January, August, September, and October. Considerable variation is exhibited in the size of the females, two specimens particularly (Bay estate, September 20, and 25, 1902) being little larger than males. The coloration exhibits the great range of variation noticed in the species of this genus, a distinct green phase being contained in the collection and represented by two specimens, one of each sex. Some females are extremely dark-coloured, which condition is also found in *O. punctata*, while others are quite pale.

This species can readily be separated from *O. punctata* by the characters given in the diagnosis, the more appreciable being the more retreating face and the more slender caudal femora.

I take pleasure in dedicating this species to Mr. H. A. Ballou, Entomologist to the Imperial Department of Agriculture for the West Indies, through whose kindness I received the present collection for study.

Schistocerca, Stal.

SCHISTOCERCA PALLENS (Thunberg).

Barbados. November 15, 1902, and June 2, 1903. [No. 10.] One male, three females.

These specimens have the tegmina more pantherine than in Cuban specimens of this species which have been examined in this connexion, but they are no doubt the same.

This species has been recorded from Cuba, Hayti, Jamaica, and St. Vincent in the Antilles.

Family TETTIGONIDAE.

Turpilia, Stal.

1874. *Turpilia*, Stal; *Recensio Orthopterorum*, ii, p. 16, 31.

Type: *T. punctata*, Stal.

TURPILIA PUNCTATA, Stal.

1874. *Turpilia punctata*, Stal; *Recensio Orthopterorum*, ii, p. 31. [Island of St. Bartholomew.]

Dominica. October, 1901. (H. M. Lefroy.) [No. 221.] One female.

Montserrat. August, 1901 (on lime tree). (H. M. Lefroy) [No. 221.] One female.

This species has previously been recorded only from the type locality.

Xerophyllopteryx (new name).

1895. *Xeropteryx*, Brunner; *Monographie der Pseudophylliden*, p. 102. (Not of Butler, *Jour. Linn. Soc.*, London, 1883, xvii, p. 203.)

XEROPHYLLOPTERYX FUMOSA (Brunner).

1895. *Xeropteryx fumosa*, Brunner; *Monographie der Pseudophylliden*, p. 103, fig. 45. [South America, Guadeloupe.]

St. Lucia. February 25, 1902, and March, 1902. (H. M. Lefroy, in part.) [Nos. 223 and 405.] Three males, one female.

This species has not been recorded since the original description, and from the known localities would appear to have a rather wide distribution. Some variation is apparent in the size of the male individuals.

Conocephalus, Thunberg.

CONOCEPHALUS OBSCURELLUS, Redtenbacher.

Barbados. (H. M. Lefroy, in part.) September 27, 1903. [No. 80.] Six males, nine females.

This series exhibits a great amount of variation in the intensity of the coloration, the size being quite constant. This species ranges from the Gulf States to Venezuela.

CONOCEPHALUS MACROPTERUS, Redtenbacher.

Barbados. September 7, 1903. [No. 384.] Two females.

St. Lucia. February, 1902. [No. 384.] One female.

Montserrat. January, 1904. (H. A. Ballou.) [No. 384.] One female.

The individual from Montserrat considerably exceeds the others in size, equalling the Venezuela female mentioned by Redtenbacher.* They all agree with a series of specimens from Jalapa, Verá Cruz, Mexico, which also exhibits considerable variation in size. This species ranges from Cuba to Buenos Ayres, and has been definitely recorded from Martinique and St. Vincent in the Lesser Antilles.

Family GRYLLIDAE.

SCAPTERISCUS, Scudder.

1868. *Scapteriscus*, Scudder; *Proc. Boston Soc. Nat. Hist.*, xi, p. 385.

The original description mentioned no included species, and in a later work† he includes eight species—*oxydactylus*, *tenuis*, *mexicanus*, *didactylus*, *vicinus*, *agassizii*, *variegatus*, and *abbreviatus*. Of these the one standing first, *oxydactylus* (Perty), can be considered the type.

SCAPTERISCUS VARIEGATUS (Burmiester).

1838. *Gr[yllotalpa] variegata*, Burmeister; *Hand. der Entom.*, ii, Abth. ii, i, p. 740. [Colombia.]

Barbados. July 10, 1903. (H. A. Ballou.) [No. 224.] One male.

This specimen has the wings shorter than the tegmina, in this resembling *S. abbreviatus*, Scudder; which, however, has the tegmina of a very different shape. The species has been recorded from St. Lucia by Saussure.

GRYLLOTALPA, Latreille.

1802. *Gryllotalpa*, Latreille; *Hist. Nat. Génér. et Partic. des Crust. et des Ins.*, iii, p. 275.

Type: *Gryllus gryllotalpa*, Linnaeus.

GRYLLOTALPA HEXADACTYLA, Perty.

1830-4. *Gryllotalpa hexadactyla*, Perty; *Delect. Anim. Art. Bras.*, p. 119, tab. xxiii, fig. 9. [In mountains of the Province of Minas Geraes, Brazil.]

St. Vincent. (H. M. Lefroy.) One specimen.

Montserrat. January, 1904. (H. A. Ballou.) [No. 224.] One specimen.

This widely distributed species has been previously recorded from Gaudeloupe, St. Vincent, and Grenada in the Lesser Antilles.

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* *Verh. K. K. Zool.-bot. Gesell.* Wien, xli, p. 402, 1891.

† *Mem. Peabody Acad.*, i, pp. 7-15, 1869.

GRYLLUS, Linnaeus.

GRYLLUS ASSIMILIS, Fabricius.

Barbados. September 22, October 25, 1902, and February 6, 1903. (C. Todd, H. M. Lefroy, and H. A. Ballou.) [No. 81.] Six males, nine females.

Dominica, Middleham. Nov. 25, 1901. (W. R. Elliot.) [No. 318.] One broken specimen.

St. Lucia. September 5, 1903. (H. A. Ballou.) [No. 81.] One female.

This species has been recorded from Martinique, St. Vincent, and Grenada.

AMPHIACUSTA, Saussure.

1874. *Amphiacusta*, Saussure; *Miss. Scient. Mex. et l'Amer. Cent.*, Orth., p. 444.

Included *annulipes* (Serville), *grandis* (Saussure), *fuscicornis* (Serville), *azteca* (Saussure), and *phalangium* (Saussure). Of these the first, *annulipes*, may be considered the type.

AMPHIACUSTA CARIBEA, Saussure.

1897. *Amphiacustes caribeus*, Saussure; *Biol. Cent. Amer.*, Orth., i, p. 248. [Guadeloupe.]

Barbados, Cottage. December 31, 1903. (R. Brown.) One male. Belleville. October 18, 1902. (R. Hamlyn-Harris.) [No. 616.] One female.

This species was previously known only from the type locality.

OROCHARIS, Uhler.

1864. *Orocharis*, Uhler; *Proc. Ent. Soc.*, Phila., ii, p. 544.

Type. *O. saltator*, Uhler.

OROCHARIS ANTILLARUM, Saussure.

1874. *Orocharis Antillarum*, Saussure; *Miss. Scient. Mex. et l'Amer. Cent.*, Orth., p. 496. [Guadeloupe.]

Antigua, Bath. January 8, 1903. [No. 617.] One male.

Barbados. (H. M. Lefroy.) [No. 617.] One male.

This species was previously known only from the original description and type locality.

ADDITIONAL NOTES ON WEST INDIAN INSECTS.

In Mr. Clark's paper (pp. 40-3) a few of the common insects are mentioned as having been seen in the islands in which he visited, but, as the writer states in the last paragraph, the object of his visit was to collect birds, and he does not claim to have made a complete survey of the West Indian insects. The orthoptera of these islands have recently been reviewed by Mr. James A. G. Rehn, in the *Entomological News* for June 1905, in a paper entitled 'Notes on a Small Collection of Orthoptera from the Lesser Antilles, with the description of a New Species of *Orphulella*,' which is reprinted in this number of the *West Indian Bulletin* (pp. 44-52).

In the following notes, prepared by Mr. Henry A. Ballou, B.Sc., Entomologist on the staff of the Imperial Department of Agriculture, it is intended not to give a complete list of West Indian insects, but rather to place on record a few of the more common insects in different orders which are of economic importance or of general interest.

HEMIPTERA.

In the Hemiptera, the most important insects are the Coccidae or scale insects. Mr. H. Maxwell Lefroy, in the *West Indian Bulletin*, Vol. III, pp. 240-70 and 295-319, deals with 120 species of scale insects, of which eighty seem to be native. They occur on a great variety of plants and certain species occur in great numbers. The orange mussel scale (*Mytilaspis citricola*) and the orange snow scale (*Chionaspis citri*) are to be found on limes, oranges, and other citrus plants in all the localities on cultivated plants, and perhaps to a greater extent on neglected or wild plants. Several species of *Lecanium*, of *Aspidiotus*, of *Dactylopius*, and *Vinsonia stellifera* are of common occurrence, and the sooty appearance of many trees and smaller plants covered with black blight, indicates the presence of one or more species of scale insects in large numbers.

The white fly (Aleyrodidae) also occurs in considerable numbers. In Barbados the cocoa-nut, the banana and other plants are affected. The white fly of the cocoa-nut has been described as *Aleyrodicus cocois*, and to its ravages has been attributed the loss of a great proportion of the cocoa-nut trees of the island. At the present time several scale insects are to be found on cocoa-nut trees.

The cane fly (*Delphax saccharivora*), while not common, occurs from time to time, and in certain years is quite abundant.

The corn fly (*Delphax maidis*) also occurs in some years in considerable numbers.

Plant lice, probably of several species, are abundant. Cotton is attacked by *Aphis gossypii*, and other plants are frequently seen with young shoots and tender leaves infested with large numbers of plant lice.

Of the larger Hemiptera, specimens of *Proarna* spp. are collected occasionally in St. Vincent, St. Lucia, and Dominica.

Of the Hemiptera-Heteroptera, the cotton stainers are perhaps the most common, occurring abundantly in the cotton fields in all the islands where cotton is grown, except Barbados. *Dysdercus andreae* is found in the Northern Islands, and *Dysdercus annuliger* in the Southern Islands: and, though this latter species has been found in Barbados, it is rarely seen.

Nezara viridula and *Edessa meditibunda* are the most common of the Pentatomidae and are found on a great variety of plants.

Several species of water bugs are found in the ponds and pools of stagnant water in the different islands, and some of them are attracted to light in houses. *Zaitha anura* occurs in Grenada, and at least two species of the family Corsidae are common in Barbados.

A species of *Emesa* is common in houses in Barbados. This is one of the thread-legged bugs and is believed to feed on mosquitos and other small insects.

The wheel bug (*Arilus cristatus*) is one of the largest and most conspicuous of the true bugs. It is common in St. Vincent and probably occurs in other of the Lesser Antilles.

The blood-sucking cone nose (*Conorhinus sanguisugus*) is fairly common in Barbados, and one report has been received of serious bites inflicted upon a child while asleep in bed. A specimen of this insect was afterwards captured in the same room in which the child slept, and as no other cause of the bites could be found they were attributed to the *Conorhinus*.

Spartocera fusca is common in several of the islands and has recently been reported as a pest of the Irish potato.

Acanthocerus lobatus is common in St. Vincent and Grenada on wild Ricinus and allied plants.

The leaf-footed bug (*Leptoglossus phyllopus*) is a handsome species not rare in St. Vincent.

The shield-back bug found in St. Lucia is a curious insect. The scutellum is developed so that it covers the entire dorsal surface of the abdomen, giving the insect much more of the appearance of a beetle than a bug at first sight. It has been found feeding on the Marie Galante cotton which grows practically wild in that island.

Mormidea upsilon, a small bug with the scutellum margined with silver-gilt in the form of a Y is not rare and occurs in several of the islands.

ODONATA.

The abundance of dragon-flies, or pond-flies as they are more often called, cannot fail to strike the visitor to Barbados as remarkable. In every open place, whether it be grassfield, cultivated land, or roadside, especially if there is any tendency to swampiness or stagnant water, numbers of these insects will be seen flying to and fro and occasionally alighting on some plant.

The most common of these is the medium-sized insect (*Erythrodiplax umbrata*) with a dark body and lighter wings which are crossed by a broad dark band near the middle. More showy than this, however, are the bright red (*Tramea abdominalis*), and the bright green (*Lepthemis vesiculosa*).

A small collection of Odonata of Barbados was recently sent from the office of the Imperial Department of Agriculture to the Academy of Natural Sciences, Philadelphia, for identification. They were examined by Dr. P. P. Calvert, who kindly forwarded the following names :—

1. *Anax amazile*, Burm.
2. *Cannacria batesi*, Kirby.
3. *Cannacria furcata*, Hagen.
4. *Erythrodiplax umbrata*, L.
5. *Ischnura ramburi*, Selys.
6. *Ischnura ramburi credula*, Hagen.
7. *Lepthemis vesiculosa*.
8. *Orthemis sulphurata*, Hagen.
9. *Pantala flavescens*, Fab.
10. *Tramea abdominalis*, Ramb.
11. *Tramea cophysa*, Hagen.

Kirby* describes nineteen species from St. Vincent and Grenada, only three or four of which seem to be included in the list of species from Barbados.

NEUROPTERA.

The Neuroptera are not represented in the West Indies by many showy insects or many that are of interest to the casual observer. The lace-wing fly (*Chrysopa* sp.) is very common and is to be found in cotton and sugar-cane fields, in grass plots, and on many plants that are affected by plant lice (Aphidae), white fly (Aleyrodidae), or small insects such as the cane fly (*Delphax saccharivora*) and other small sucking insects.

White ants (Termitidae) are very abundant and are the cause of serious damage to wood work in houses and to furniture. In Barbados, white ants are best known from these injuries and the covered galleries through which they travel: but, in other islands, the nests are frequently seen on the trunks of trees.

The bird-lice or biting lice, which are members of this family, occur as pests of domestic birds in the West Indies. The book lice, which are commonly seen running about among books, are also members of this family, and are very common. Certain of these small Neuropterans are very destructive to museum specimens, while at least one (*Psocus* sp.) is to be found on leaves infested with scale insects, on which it is believed to prey. The *Psocus* makes a very delicate web on the leaf, under which it lives.

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* On some small collections of Odonata (Dragon-flies) recently received from the West Indies by W. F. Kirby, F.L.S., F.E.S., Assistant in Zoological Department, British Museum. *Ann. and Nat. Hist.*, Ser. 6, Vol. xiv, October, 1894.

LEPIDOPTERA.

In Mr. Clark's paper the names of eight species of butterflies are given, and it is stated that several Lycaenas and a number of skippers also occur.

In addition to these, *Papilio polydamas* might be mentioned as occurring occasionally. The skippers most common in Barbados are *Calpodes ethlius* and *Eudamus proteus*. The larva of *Calpodes ethlius* is known in Barbados as the canna worm, the canna being its principal food plant: in St. Vincent it is known as the arrowroot worm. In some seasons it occurs there in such numbers on the arrowroot plantations as to make it a serious pest. A pretty orange and black skipper occurs in St. Vincent (? *Thymelicus brettus*), and a similar one in Dominica. The latter is slightly larger and has a larger proportion of black on the wings.

Two pretty butterflies are quite common in the ravines and on the mountain-sides in Montserrat. One of these, the Zebra (*Heliconius? charitonius*), is black and yellow; it is found also in Nevis. The other is a handsome black butterfly with a marginal row of bright red spots on the hind wings.

Anartia jatrophe occurs in St. Vincent, Grenada, St. Lucia, and Dominica.

Among the moths, the Sphingidae are well represented.

The tobacco moth (*Protoparce lucetius*), the sweet potato moth (*Protoparce cingulata*), the frangipanni hawk moth (*Pseudosphinix tetrio*), *Chaerocampa sumedon*, *Dilophonota ello*, and *Enyo lugubris* are all common and may frequently be taken about lights at night.

Lilies are frequently attacked by greenish caterpillars with black spots. These often occur in large numbers on the broad-leaved lily, and are the larvae of *Euthisanotia amaryllidis*.

The night witch (*Erebus odoratus*) is not rare. This is one of the largest of the moths of the Antilles.

The cotton worm (*Aletia argillacea*) is a common pest in the cotton fields in most of the islands of the Lesser Antilles, but St. Vincent is a notable exception. Although large areas of cotton have been cultivated in that island during the past three years, not a single attack of the cotton worm has been observed, nor have any specimens been collected.

The corn ear worm (*Laphygma frugiperda*) is also a common pest, and the moths are frequently attracted to light.

The pink under-wing (*Utetheisa ornatrix*) is commonly seen in the fields of Barbados sour grass. The larva feeds on *Crotalaria* sp., a common weed.

The moth borer of the cane (*Diatraea saccharalis*), though a very common pest in the larval state, is not often seen as an adult.

The Micro-lepidoptera are fairly numerous, being attracted to light during the wet season.

COLEOPTERA.

The Coleoptera of Barbados do not include many of the striking forms of beetles found in some of the other West India Islands where there is an abundance of wild land and forest.

In Barbados, however, several of the economic insects are beetles, and some of them are extremely difficult to deal with on account of their habits.

The most important of the Coleoptera in Barbados are the Rhyncophora, or snout beetles, which include the weevil borer of the sugar-cane (*Sphenophorus sericeus*) and the root borer of the sugar-cane (*Diaprepes abbreviatus*). The rice weevil (*Calandra oryzae*) is also quite common.

Diaprepes splengeri is common in St. Vincent, and is known as a pest on orange and other citrus trees in Porto Rico, but it does not seem to be recorded in the intermediate islands. In Dominica and Montserrat, *Epicaerus varidus* feeds on the leaves of lime and other citrus plants. The palm weevil (*Rhynchophorus palmarum*) occurs in Dominica, Grenada, and Trinidad, and the banana weevil (*Sphenophorus sordidus*) has occasionally been an abundant pest in Dominica.

A small, striped beetle is sometimes attracted to the lights in houses in great numbers. This is *Copidita lateralis*. It is said to produce a painful blister if one is crushed on the skin of a person, as sometimes happens in brushing them away.

Hopatrinus gemmellatus, *Tribolium ferrugineum*, and *Zophobas morio* are the most common of the darkling beetles.

The pea weevils are represented by *Bruchus chinensis* and *Bruchus quadrimaculatus*, which feed on the pigeon pea.

Several of the Cerambycidae occur in Barbados. The tobacco flea beetle (*Epitrix parvula*), and a small steel-blue flea beetle that attacks the sweet potato, occur as pests at times, while *Homophoeta aequinoctialis* is very abundant on vervain (*Stachytarpha jamaicensis*), a common wayside weed. The beautiful little tortoise-shell beetles (*Coptocyla* spp.) are frequently to be seen on sweet potato and other plants.

The long-horned beetles include many showy forms, some of which are quite common. During the past year a number of trees of *Albizzia Lebbek* have died in Barbados, and in all cases that have been investigated they have been found to be badly infested by *Chlorida festiva*, a large insect with green and gold wing-covers, russet-brown legs, and antennae much longer than the body.

The species of *Leptostylus* are bark borers, the grub living in the soft wood and bark of trees and woody plants. *Leptostylus praemorsus* is the bark borer of limes.

Other longicorns of common occurrence are *Eburia decemmaculata*, a dark-brown insect with yellow spots on the wing covers; *Achryson surinamum*, a pale-brown insect with black markings on the wing covers; *Phryneta verrucosa*; *Trachyderes succinctus*, and *Polyraphis spinosa*. In Grenada and other

cacao-growing islands *Steirastoma depressum* occurs as a borer in the trunks and larger branches of the cacao trees.

Oncideres amputator occurs in St. Lucia as a pruner of Pois doux (*Inga vera*) and Sarronette trees: it is reported in St. Vincent to attack cacao.

The Lamellicornia include some of the largest of the tropical beetles and also some of the commonest. The ordinary hardback (*Ligyrus tumulosus*) is one of the most frequent visitors to lights in Barbados; and is found all through the Lesser Antilles. A related species (*Cyclocephala* sp.) is not of common occurrence.

Tomarus bituberculatus has been known as a pest of bananas and plantains in St. Lucia, eating into the base of the newly planted suckers, and sometimes causing the death of the plant.

The hercules beetle* (*Dynastes hercules*) occurs in the more wooded islands, as do also several species of *Passalus* and *Neleus*.

The small fire-fly (*Aspidosoma ignitum*), which is so common in many of the West India Islands, does not occur naturally in Barbados or Antigua, but recently reports have been received of the appearance of fire-flies in these islands, which would indicate that these insects have been introduced. During the past year a few specimens of the larger fire-fly (*Phyrophorus noctiluca*) have been captured in Barbados, and it may be that this is the species that has been seen here, and not *Aspidosoma ignitum*.

Water beetles are very common in standing water in Barbados; *Hydrophilus ater*, *Tropisternus lateralis*, and *Eunectes occidentalis* being the most common.

DIPTERA.

The Diptera or two-winged flies are numerous and of great importance in tropical countries, rather on account of the annoyance they cause and the relation they bear to certain diseases, than on account of their beauty or remarkable forms, or their importance as pests of agriculture.

The mosquitos are, perhaps, first in importance, since certain species act as intermediate hosts in such diseases as yellow fever, malaria, and filaria. Six species of mosquito are said to be found in Barbados, two of which are common, the Scots grey (*Stegomyia fasciata*), the yellow fever mosquito, and the common brown mosquito (*Culex fatigans*), the intermediate host of filaria. The Scots grey, although very annoying, is to be considered harmless on account of the rare occurrence of yellow fever. The malaria mosquito (*Anopheles* sp.) does not occur in Barbados, although extremely numerous in some of the neighbouring islands. The holes of land crabs are usually inhabited by a mosquito, the larvae of which breed in the water in the bottom of these holes. The

*Mr. A. H. Verrill of Dominica has recently (about March, 1905) published in leaflet form the description of a new species of *Dynastes* ([illegible]) which he has found in that island. It is smaller than *D. hercules* and has characteristic differences in the thoracic and cephalic horns. [Ed. *W.I.B.*]

mosquito-like *Corethra* is also common in many parts of the island.

The family Chironomidae is well represented, and a small crane-fly (family Tipulidae) is fairly common about Barbados.

The Ceciomyiidae are represented by the red maggot of cotton (*Porrichondyla gossypii*) which lives under the bark of the stems of the cotton plants, and at times is so numerous as to be a serious pest.

Sand flies (? *Ceratopogon* sp.) are very troublesome at certain seasons along the sandy beaches in the southern part of the island.

The moth-like flies of the family Psychodidae are represented by one or more species of *Psychoda*, which are found in damp places where the larvae live in foul water or very moist earth. A species of *Conops* is common, and *Phora scalaris* is abundant, breeding freely in all kinds of decaying fruit and other vegetable matter.

Sarcophaga trivittata has been bred from pupae of the cotton worm (*Aletia argillacea*) and was supposed to be a parasite, but this has not been fully proved. As the habit of this species is rather to breed in dead or decaying matter than to attack living insects, it will be necessary to make further observations before arriving at any definite conclusion.

A small greenish fly with barred wings (*Euxesta stigmatias*) is very common in fields of corn and cotton.

The following also are frequently seen: *Anastrepha serpentina*, *Sturmia distincta*, and *Eristalis vinctorum*, while the winged bird-tick (*Olfersia americana*), is occasionally captured.

HYMENOPTERA.

The bees, wasps, and ants found in Barbados include a fairly large number of species, some of which are abundant.

Of the parasitic Hymenoptera, the curious *Evania laevigata*, *Ophion bilineatum*, *Chalcis annulatus*, and *Trichogramma pretiosa* are all of frequent occurrence.

The eggs of the American cockroach (*Periplaneta americana*) are frequently parasitized by a small hymenopteron, and a similar insect destroys the larvae of the tailed-skipper (*Eudamus proteus*), which is frequently found completely covered with the white cocoons of this parasite.

Schomburgk in his *History of Barbados*, mentions four species of ants in Barbados: the sugar ant (*Formica omnivora* Linn.), the great-headed ant (*Formica cephalotes*, Fabr.), the caustic ant (*Formica caustica*, Kollar) and the small sugar ant (*Formica saccharivora*). The first of these, *Formica omnivora*, was a serious pest in the latter part of the eighteenth and early part of the nineteenth centuries, entirely destroying fields of sugar-cane. An ant, which may be of the same species, is found in Barbados at the present time but it is not known as a pest and does not occur in anything like the extraordinary numbers recorded by Schomburgk. The great-headed ant (*Formica cephalotes*, Fabr.) is evidently the same as the

parasol ant of Trinidad. It is not known to occur in Barbados at the present time, but is a serious pest in Trinidad and Tobago.

A small black ant, frequently seen running about on the trunks of trees, has the peculiar habit of carrying the abdomen elevated over the thorax. This is a species of *Cremastogaster*. It does not often sting but is reported to be able to do so. The crazy or mad ant, as it is called from its very rapid and apparently aimless way of running about, is a great nuisance in houses, where it infests sugar and other household supplies. There are several kinds of stinging ants in Barbados, the stings of some of which are quite painful.

The common mason bee (*Pelopoeus cementarius*) is frequently seen in and about buildings, and one species of *Sphex* is occasionally captured.

Several very beautiful species of the Pompilidae are common in the Leeward Islands, but only one (*Pompilus tenebrosus*) seems to be found in Barbados.

A large dark-coloured bee-like insect, with two large orange-red spots on the dorsal surface of the abdomen, is the female of *Dielis dorsata*. It may frequently be seen burrowing into the soil especially in sandy loams. *Elis atrata*, a related species, is said to be parasitic on the grub of the fiddler beetle (*Praepodes vittatus*) which attacks orange trees in Jamaica. It is suspected that *Dielis dorsata* may have a similar habit, but this does not seem to have been proved. The male of this species is yellow and black and is very different in appearance from the female. Both sexes are common flower visitors.

The large carpenter bee (*Xylocopa fimbriata*) builds in old posts, dead stubs of trees, etc., and is a frequent visitor to flowers. When the tubular corolla is too deep and narrow to allow the bee to get to its base, as in many Ipomoeas, the insect cuts a slit near the base of the corolla, and is thus able to get at the nectaries without entering the flower. They have been observed frequently to do this, and at times nearly every flower on an Ipomoea vine visited by this insect will be found to be cut in this way. The female of this species is shiny black, the male a pale reddish-yellow.

Xylocopa aeneipennis, a small carpenter bee with fuscous wings, is also common. The male of this species is reddish-black covered with pale-yellowish hairs.

Of the leaf-cutting bees, *Megachile martindalei* is common, *Megachile flavitarsata* less so, while a third (? *Megachile multidens*) is occasionally found.

A handsome bee, commonly taken on flowers, builds a mud nest on rocks and cliffs. The colour is black with dense yellowish pubesence on the thorax and legs, and a red spot on the tip of the abdomen. This is probably a species of *Melissodes*.

A handsome species of *Coelioxys* and a small species of *Bombus* are also of occasional occurrence.

BIBLIOGRAPHY OF WEST INDIAN INSECTS.

The following papers are, for the most part, reports on the collections of Mr. H. H. Smith, who was sent to the West Indies by Mr. F. D. Godman, F.R.S., to assist the Committee appointed by the British Association for the Advancement of Science and the Royal Society to investigate the fauna and flora of the Antilles. The collections were mostly made in St. Vincent, Grenada, and the Grenadines. A full list of the papers dealing with these collections was published in the Report of the British Association for the Advancement of Science, Dover, 1899, p. 441, from which the following list of papers dealing with insects is extracted.

All material that remained unworked-out on July 5, 1899 was presented to the Trustees of the British Museum.

In addition to these, it may be mentioned that papers dealing with insects of economic importance in the West Indies have appeared in the various publications of the Imperial Department of Agriculture:—

ORTHOPTERA.

Kirby, W. F. ... ... Descriptions of new Species of Phasmidae from Dominica, Santa Lucia, and Brazil (Theresopolis), in the collection of the British Museum. *Ann. and Mag. Nat. Hist.*, III, 1889, pp. 501-4.

Brunner v. Wattenwyl, C. and Redtenbacher, J. On the Orthoptera of the island of St. Vincent, West Indies. *Proc. Zool. Soc. Lond.*, 1892, pp. 196-221, with plates 15-7.

Brunner v. Wattenwyl, C. On the Orthoptera of the island of Grenada, West Indies. *Proc. Zool. Soc. Lond.*, 1893, pp. 599-611, with plate 52.

ODONATA.

Kirby, W. F. ... ... On some small collections of Odonata (Dragon-flies) recently received from the West Indies. *Ann. and Mag. Nat. Hist.*, XIV, 1894, pp. 261-9.

HEMIPTERA.

Uhler, P. R. ... ... An enumeration of the Hemiptera-Homoptera of the island of St. Vincent, West Indies. *Proc. Zool. Soc. Lond.*, 1895, pp. 55-84.

" " ... ... On the Hemiptera-Heteroptera of the island of Grenada, West Indies. *Proc. Zool. Soc. Lond.*, 1894, pp. 167-224.

" " ... ... A list of the Hemiptera-Heteroptera collected in the island of St. Vincent, by Mr. Herbert H. Smith,

with descriptions of new genera and species. *Proc. Zool. Soc. Lond.*, 1893, pp. 705-19.

Uhler, P. R. ... ... A list of the Hemiptera-Heteroptera of the families Anthocoridae and Ceratocombidae collected by Mr. H. H. Smith in the island of St. Vincent, with descriptions of new genera and species. *Proc. Zool. Soc. Lond.*, 1894, pp. 156-60.

LEPIDOPTERA.

Hampson, G. F., Sir ... On the Geometridae, Pyralidae, and allied families of Heterocera of the Lesser Antilles. *Ann. and Mag. Nat. Hist.*, XVI, 1895, pp. 329-49.

" " " ... The moths of the Lesser Antilles. *Trans. Ent. Soc. Lond.*, 1898, pp. 241-60, with plate 17.

Walsingham, Lord ... On the Micro-Lepidoptera of the West Indies. *Proc. Zool. Soc. Lond.*, 1891, pp. 492-549, with plate 41.

COLEOPTERA.

Waterhouse, C. O. ... Observations on some Buprestidae from the West Indies and other localites. *Ann. and Mag. Nat. Hist.*, XVIII, 1896, pp. 104-7.

Mathews, A. ... ... Corylophidae and Trichopterygidae found in the West Indian Islands. *Ann. and Mag. Nat. Hist.*, XIII, 1894, pp. 334-42.

Grouvelle, A. ... ... Clavicornes de Grenada et de St. Vincent (Antilles) récoltees par Mons. H. H. Smith. *Notes from the Leyden Museum*, XX, 1898, pp. 35-48.

Gorham, Henry S. ... On the Serricorn Coleoptera of St. Vincent, Grenada, and the Grenadines, (Malacodermata, Ptinidae, Bostrychidae) with descriptions of new species. *Proc. Zool. Soc. Lond.*, 1898, pp. 315-33, and part of plate 27.

" " ... On the Coleoptera of the families Erotylidae, Endomychidae, and Coccinellidae, collected by Mr. H. H. Smith in St. Vincent, Grenada, and the Grenadines, with descriptions of new species. *Proc. Zool. Soc. Lond.*, 1898, pp. 334-43, and part of plate 27.

Gahan, C. J. ... ... On the Longicorn Coleoptera of the West India Islands. *Trans. Ent. Soc. Lond.*, 1895, pp. 79-140, with plate 2.

Champion, G. C. ... ... On the Heteromerous Coleoptera of St. Vincent, Grenada, and the Grenadines. *Trans. Ent. Soc. Lond.*, 1896, pp. 1-54, with plate 1.

Champion, G. C., ... On the Serricorn Coleoptera of St. Vincent, Grenada, and the Grenadines. *Trans. Ent. Soc. Lond.*, 1897, pp. 281-96.

Jacoby, M. ... ... A list of the Phytophagous Coleoptera obtained by Mr. H. H. Smith at St. Vincent, Grenada, and the Grenadines, with descriptions of new species, Crioceridae—Galerucidae *Trans. Ent. Soc. Lond.*, 1897, pp. 249-80.

DIPTERA.

Williston, S. W. ... ... On the Diptera of St. Vincent, West Indies, (Dolichopodidae and Phoridae by J. M. Aldrich). *Trans. Ent. Soc. Lond.*, 1896, pp. 253-446, with plates 8-14.

HYMENOPTERA.

Riley, C. V., Ashmead, W. H., and Howard, L. O. ... Report upon the Parasitic Hymenoptera of the island of St. Vincent. *Jour. Linn. Soc. (Zool.)*, 1894, XXV, pp. 56-254.

Ashmead, W. H. ... Report on the Parasitic Hymenoptera of the island of Grenada, comprising the families Cypinidae, Ichneumonidae, Braconidae, and Proctotrypidae. *Proc. Zool. Soc. Lond.*, 1895, pp. 742-812.

Forel, A. ... ... Formicides de l'Antille St. Vincent. Récoltées par Mons. H. H. Smith. *Trans. Ent. Soc. Lond.*, 1893, pp. 333-418.

.. .. Quelques Formicides de l'Antille de Grenada. Récoltées par Mons. H. H. Smith. *Trans. Ent. Soc. Lond.*, 1897, pp. 297-300.

COTTON STAINERS.

BY H. A. BALLOU, B.Sc.,

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The cotton stainers of the genus *Dysdercus* are widely distributed in the cotton-growing districts of the world. Although a great many species have been catalogued and described, very little has been done in recording their habits and life-histories. The notes on habits and life-histories embodied in this paper have been made at the laboratory of the Imperial Department of Agriculture at Barbados on insects in captivity which have been received from the other islands, or have been reared from eggs produced by such insects.

The present paper contains descriptions of the species known to occur in the Lesser Antilles and Trinidad, a list of the species from tropical and subtropical America, and references to publications in which these species are described or catalogued. Two species and one variety, believed to be new, are described, and notes on life-history, habits, food plants, and on geographical distribution are added.

THE GENUS DYSDERCUS.

The genus *Dysdercus* belongs to the family Pyrrhocoridae of the Hemiptera-Heteroptera. The Pyrrhocoridae are separated from the nearly related family Lygaeidae only by the absence of o elli, and these two families are separated from the Coreidae principally by the insertion of the antennae, which in the Coreidae are inserted on the upper parts of the sides of the head, and in the Lygaeidae and Pyrrhocoridae on the lower parts of the sides of the head. Sharp (*The Cambridge Natural History*, Insects, Part II, p. 548.) includes *Dysdercus* in the Lygaeidae.

Believing this to be due to an error, the writer of this article wrote to Dr. Sharp as follows :—

'I notice in *The Cambridge Natural History*, (Insects, Part II, p. 548.) that you have included *Dysdercus* in the family Lygaeidae, and then under the family Pyrrhocoridae the statement occurs 'Distinguished from the Lygaeidae only by the absence of ocelli.' Most authors include *Dysdercus* in the Pyrrhocoridae, and I may say that I am unable to distinguish any ocelli in the species of *Dysdercus* that I have examined. I beg, therefore, to inquire whether there are other reasons for the position you give to this genus.'

Replying to this letter, Dr. Sharp wrote as follows :—

'Thanks for pointing out the error in *The Cambridge Natural History* as to *Dysdercus*. It belongs to Pyrrhocoridae. The original intention was to treat Pyrrhocoridae as only a division of Lygaeidae, and the mistake probably originated in this way.'

In the following list are given the species of *Dysdercus* which are recorded from tropical and subtropical America, with reference to original descriptions and dates, so far as these are known to the writer:—

1. *albidiventris*, Stal; 1854	...*Enumeratio Hemipterorum* 1870-7.
2. *andreae*, Linnaeus = suturalis, Fabricius	...*Hemiptera Fabriciana*, 1858-64. *Enumeratio Hemipterorum.* 1870-7.
3. *annuliger*, Uhler; 1894	...Hemiptera-Heteroptera of Grenada, *Proc. Zool. Soc. Lond.*, 1894.
4. *annulis*, Herrich-Schaeffer ...	
5. *chiriquinus*, Distant ...	...*Biologia Centrali Americana*, Tab. xxi, fig. 22.
6. *concinnus*, Stal; 1861	...*Enumeratio Hemipterorum*, 1870-7.
7. *delauneyi*, Lethierry; 1880	...*Ann. de la Soc. Entom. de Belgique*, 1880, xxv, p. 10.
8. *fervens*, Walker ...	...*Catalogue of the Hemiptera*, Part v, p. 182.
9. *flavolimbatus*, Stal; 1861	...*Enumeratio Hemipterorum*, 1870-7.
10. *incertus*, Distant ...	...*Biologia Centrali Americana*, Tab. xxi, fig. 7.
11. *jamaicencis*, Walker ...	...*Catalogue of the Hemiptera*, Part v, p. 182.
12. *longirostris*, Stal ...	...*Enumeratio Hemipterorum*, 1870-7.
13. *mimus*, Say	... " "
14. *mundus*, Walker ...	...*Catalogue of the Hemiptera*, Part v, p. 181.
15. *obliquus*, Herrich-Schaeffer; = *bimaculatus*, Stal ...	...*Die Wanzenartigen Insecten*, 1831-53, vii, pl. ccxxiii, fig. 701, p. 19. *Enumeratio Hemipterorum*, 1870-7.
16. *ochreatus*, Say ...	...
17. *oncopeltus*, Distant ...	...*Biologia Centrali Americana*, Tab. xxi, fig. 13.
18. *peruvianus*, Guer. ...	...*Enumeratio Hemipterorum*, 1870-7.
19. *ruficeps*, Perty ...	... " "
20. *ruficollis*, Linnaeus ...	... " "
21. *rufipes*, Stal ...	... " "
22. *rusticus*, Stal ...	... " "
23. *sanguinarius*, Stal ...	... " "
24. *splendidus*, Distant ...	...*Biologia Centrali Americana*, Tab. xxi, fig. 14.
25. *suturellus*, Herrich-Schaeffer = *suturalis*, Burmeister	...*Die Wanzenartigen Insecten*, 1831-53, vi, p. 76.

The information contained in the preceding table has, for the most part, been furnished by Dr. H. T. Fernald, who has kindly looked up references and copied descriptions; and for this very material assistance, the writer desires to record here his thanks.

In the British colonies of the Lesser Antilles, two species of *Dysdercus* have been recognized: *D. andreae*, Linn., in the Northern Islands, and *D. annuliger*, Uhler, in the Southern Islands. In the French Islands—Martinique and Guadeloupe—*D. delauneyi*, Lethierry, has been recorded. The descriptions of these species together with some of the variations that have been noticed are given herewith:—

Dysdercus andreae, Linnaeus.

The following description is a translation of that given by Stal in *Hemiptera Fabriciana*, 1858-64:—

'Rufo-testaceous or sanguineous; antennae (except a narrow area at the base), sometimes also a transverse line within the apical margin of the thorax, a narrow margin of the clavus inside, a sub-transverse spot within and about the middle of the apical angle of the corium, the membrane, two apical segments of the rostrum, and the feet black; bases of the femora verging to sanguineous; anterior and posterior margins of the thorax, suture of the clavus, apical margin of the corium, pectoral and ventral (abdominal) fasciae (sides) whitish, these very often black-margined; margin of the membrane white. Length, 8-12½ mm.; width, 2⅓-4 mm.'

Specimens of *D. andreae* that have been examined show little variation, either in specimens from the same island, or in those from the different islands. The principal variations occur in the colour of the clavus. This, in some cases, is thoroughly suffused with black, making a sharp contrast with the bright sanguineous scutellum: and in other cases is very faintly tinged with blackish, which does little more than modify the reddish ground colour.

Dysdercus delauneyi, Lethierry.

The following is a translation of the description given by Lethierry in a paper, 'Liste des Hémiptères recueilis par M. Delauney à la Guadeloupe, la Martinique et St. Barthilemy,' in *Ann. de la Soc. Entom. de Belgique*, 1880, xxv, p. 10:—

'Sanguineous: antennae black (except a white ring at the base of fourth segment, and basal part of the first which is sanguineous), apical segment of the rostrum, posterior part of pronotum, all the hemi-elytra including the membrane (except fine white border of the cell), and the feet (except basal part of the femora), and the basal part of each abdominal segment black. Length, 10-12 mm.

'Variations—posterior part of pronotum and hemi-elytra fusco-rubris or obscurely red, spotted, membrane always black bordered with white. Near *D. ruficollis*, Linn., but distinct by the black bands of the ventral segments, and the general colour, which varies little.'

Dysdercus annuliger, Uhler.

The description of this species appeared in a paper by P. R. Uhler on 'The Hemiptera-Heteroptera of the Island of Grenada, West Indies' in the *Proc. Zool. Soc. Lond.*, 1894, and is as follows:—

'Form of *D. suturellus*, H.-Schf., but differing from that species in having a white ring at the base of the apical joint of the antennae, and in lacking the white cross on the inner margin of the corium and clavus. There are two principal patterns of marking in this insect: one in which the upper surface is dusky black, with the exception of the head, the anterior two thirds of the pronotum, and the base of the scutellum, which are red; in the other the insect is red above, excepting the base of the pronotum and the membrane, which are black. In the female the underside is red, with a black edge to the basal margin of the ventral segments and pleural sutures. In the male most of the venter is white, as are also the collum and posterior border of the pleural pieces. The rostrum of the male usually reaches to the middle of the second ventral segment, but in the female it extends only to the basal segment. Varieties occur which connect the two extremes of colour. The legs vary in the amount of red upon the femora and tibiae. Many of the specimens have these members piceous blackish.

'Length to tip of abdomen, male 8-10 mm.; female 10-12 mm.; width of pronotum, $2\frac{3}{4}$-4 mm.

'This species is also closely related to *D. ruficollis*, Linn., but it is a much larger insect, with a longer head, exactly as in *D. suturellus*, H.-Schf., and with a proportionately longer rostrum in both sexes. In *D. ruficollis* all the specimens I have examined were marked with a more or less distinct black dot behind the middle of the corium.'

Specimens of *D. annuliger* that have been examined show that variations in colour, in addition to those indicated by Uhler in the original description, occur in specimens from the different islands. Specimens from Grenada, St. Vincent, Dominica, and Guadeloupe agree closely in colour, and present the variations referred to above as mentioned by Uhler. St. Lucia specimens in general, however, differ from these, although gradations of variation connect the extreme St. Lucia colour pattern with the ordinary Grenada pattern. St. Lucia specimens differ from the types, in that the reddish portions have a tendency to be yellowish, and not the typical sanguineous; but specimens occur, which show the latter. The pattern also exhibits a smaller amount of black. In Grenada, St. Vincent, Guadeloupe, and Dominica specimens the wings are generally suffused with black, as are also the scutellum, the posterior portion of the pronotum, and the legs. In St. Lucia specimens, on the other hand, the black of the wings is sometimes confined to the membrane, and though it frequently suffuses through the corium and clavus, there is a tendency to show much more red than in the specimens from the other islands. The scutellum and pronotum

are generally free from black in St. Lucia specimens, and there is generally very little black in the legs.

Comparison of the descriptions of *D. annuliger* and *D. delauneyi*, and of these with the specimens, indicated that these names were synonymous.

Specimens of *D. annuliger* from St. Vincent were sent to Dr. L. Vitrac, Guadeloupe, in exchange for specimens of *D. delauneyi*. The following is quoted from a letter from him to the Imperial Commissioner of Agriculture, and gives the decision which he arrived at by the comparison of these specimens:—

'I have safely received the hemipterous insect from St. Vincent, which you name *Dysdercus annuliger*. I have compared it minutely with the *D. delauneyi*, Leth., in my collection, of which the types were determined more than twenty years ago by M. Lethierry himself. There is no doubt the two insects are identical.'

This is in accordance with the conclusion formed by the writer of this article, and since the description of *D. delauneyi* was published in 1880 and that of *D. annuliger* in 1894, the name of *D. delauneyi* should stand, and *D. annuliger* should be sunk as a synonym of it.

NEW SPECIES.

Dysdercus fernaldi, n. sp.

The ground colour is bright ferruginous, with lemon-yellow, black, and whitish markings.

Head bright red ; eyes small, shiny black ; rostrum reaching the middle of the third ventral segment : the apical entirely, and the third segment partly suffused with piceous ; antennae black, except extreme base of first segment which is ferruginous, and a narrow ring at base at apical segment which is whitish or tinged with ferruginous.

Prothorax above ferruginous, the narrow anterior collar pale, bordered behind with black, interrupted by lateral flanges, and on median line below. Transverse callus ferruginous slightly tinged with black from the transverse furrow, disk more or less suffused with black. Pro-pleurae ferruginous with pale areas (fasciae) at base of anterior legs, and on posterior border. Meso- and meta-pleurae ferruginous, with tinges of black on fore borders, and more prominent pale fasciae on hind borders ; scutellum dark ferruginous.

Legs ferruginous ; tarsi and tibiae entirely, femora partly suffused with black. Fore femora armed with one pair of slender spines and one or two pairs of very small spinules ; tarsi finely pubescent with pale hairs.

Hemi-elytra lemon-yellow ; membrane black, sometimes violaceous, bordered on outer margin with pale fuscous.

Abdomen and ventral segments ferruginous, tinged with yellow or greenish, with a narrow black anterior margin.

Female: length, $10\frac{1}{2}$-11 mm.: width, 4-$4\frac{1}{2}$ mm.; to tips of wings, 12-$12\frac{1}{2}$ mm.

Male: length, 8-10 mm.; width, $3\frac{1}{2}$-4 mm.; to tips of wings, 9-$11\frac{1}{2}$ mm.

This species is found in Grenada, and has been described from two male and two female specimens, of which one male and one female were collected by the writer at Sauters, in May 1904; the other male and female were taken *in coitu* by Mr. R. D. Anstead, B.A., Agricultural Superintendent, at the Botanic Station in 1905.

It is believed to be a new and distinct species, and the writer has pleasure in dedicating it to Dr. H. T. Fernald, through whose kindness the descriptions of the species of *Dysdercus*, listed above, have been obtained.

Dysdercus howardi, n. sp.

The ground colour is bright ferruginous, the markings are black, yellow, white and silvery.

Head red; eyes black, reniform, prominent; antennae black, except base of first segment which is ferruginous, and narrow basal ring on apical segment which is whitish. Length of antennae equal to two-thirds length of body. The third antennal segment is the shortest, the second slightly longer, the first and fourth equal, slightly longer than the second, and twice the length of the third. Apical segment slightly pruinose. Rostrum ferruginous, except apical segment which is more or less suffused with piceous, reaching to distal margin of second abdominal segment in the male and a little beyond in the female.

Prothorax ferruginous, bordered anteriorly by a whitish collar, narrow above, broader below, interrupted only by the lateral flanges (carinae) of the pronotum, immediately behind each eye. This collar bordered posteriorly with black. Lateral carinae ferruginous, tinged slightly with ochraceous. The narrow transverse callus ferruginous, the transverse furrow blackish, the broad posterior area (disk) of pronotum ochraceous, or more or less suffused with black, posterior border with narrow, black margin. Pronotum all sparsely coarsely punctate. Pro-pleura ferruginous, anterior collar and large posterior fasciae ivory white; these latter extend to above the coxae, and, passing in front, meet on the prosternum between the anterior coxae. Meso- and meta-plurae with similar fasciae on posterior borders, but narrower than on pro-pleura and do not meet below. A medium longitudinal pale ridge on meso- and meta-sternum. Scutellum prominent, triangular, brighter than the hemi-elytra.

Legs slender, ferruginous; tip of femora, and the tibiae slightly tinged with piceous; the tarsi black, clothed with pale hairs. Anterior femora armed beneath, near apex, with a pair of spines and a few (four) spinules.

Hemi-elytra bright ochraceous, or slightly tinged with blackish, coarsely punctate, without distinct spots or markings. Membrane black, narrowly pale bordered; veins prominent. Outer (costal) wing margins of female are slightly curved outwardly, those of male, straighter and more nearly parallel.

Abdomen, segments suffused with ivory varying to greenish white, all, except the first, with a narrow black line on anterior (basal) margin.

Female : length, 12-15 mm. ; width, 3½-5 mm.

Male : length, 10½-12½ mm. ; width, 3-4 mm.

This species is found in Trinidad and is described from numerous specimens received from Professor Carmody, F.I.C., Government Analyst, and Mr. J. H. Hart, F.L.S., Superintendent of the Royal Botanic Gardens, in addition to those collected by the writer. It is dedicated to Dr. L. O. Howard, Chief of the Bureau of Entomology of the U.S. Department of Agriculture, to whom the writer is indebted for the identification of many West Indian insects, especially *Dysdercus annuliger* and *Dysdercus andreae.*

D. howardi, var. *minor*, n. var.

The variety *minor* differs from the species in being smaller in size and darker in colour. It has a longer rostrum, reaching the middle of the third ventral segment, whereas the rostrum of *howardi*, reaches only the anterior margin of the same segment. In *howardi*, the white prothoracic collar is margined with black posteriorly only, while in *minor* there is a fine black margin both before and behind the white collar, the anterior one frequently being the more prominent.

The scutellum is darker in the variety than in the species; the spines on the anterior femora are shorter and more blunt, and there are, usually, no spinules. The black line on the anterior margin of the ventral segments is narrower.

Female : length, 9-11½ mm. ; width, 3-4 mm.

Male : length, 8½-11 mm. ; width, 3-3½ mm.

This variety occurs in Trinidad, and was taken on cotton plants with the species. The specimens from which it has been described were forwarded to the Imperial Department of Agriculture by Professor Carmody, along with the specimens of *D. howardi* mentioned above.

NOTES ON LIFE-HISTORIES.

D. andreae.—Specimens of this species were received from Montserrat on February 13, 1904, and in the box with them were a number of eggs. These had been laid since the parcel was made up for sending (February 10), and twelve of them hatched on the 19th., so that the duration of the egg stage was not more than nine days. These newly hatched insects began to moult on March 1, the first larval stage occupying eleven days. None lived to the second moult.

On February 24, a pair of adults was found *in coitu*, remaining in this condition until the 26th. On February 27, the female produced thirty-five eggs, before 11.30 a.m. On March 4, twenty-five of these eggs hatched, which makes, in this case, a period of only six days in the egg stage.

D. delauneyi.—Specimens of this species were received from St. Vincent on May 6, 1905. When received, there were several

adults and one immature specimen. Three pairs were found *in coitu* on arrival. These were separated from the remainder and put into a box together. On May 7, they were taken out and placed in separate boxes. These were numbered 1, 2, and 3. Pairs numbered 1 and 3 were still mating; but in No. 2 the male and female had separated, and there were twenty-four eggs in the box. These were ascribed to the female of No. 2, and they hatched on the 13th. Pair No. 1 was *in coitu* when received on May 6 and also when examined on the 7th. and on the 8th. On May 10, a few eggs were found in the box, and on the next day forty-four eggs had been deposited. These hatched on the 15th. Pair No. 3 was *in coitu* on the 6th. and 7th. and forty-two eggs were found on the 9th. These hatched on the 13th.

On May 7, four pairs, numbered 4, 5, 6, and 7, were found *in coitu* and were put into numbered boxes. Pair No. 4 was *in coitu* on the 7th. and 8th. and thirty-six eggs were found on the 11th., none of which hatched. On May 12, this pair was again *in coitu* but no more eggs were produced. Pair No. 5 produced no eggs. Pair No. 6 produced twenty eggs on the 9th., which hatched on the 15th. These insects were *in coitu* again on the 11th. but no more eggs were laid. Pair No. 7 was *in coitu* on the 7th., 8th., and 9th., and eleven eggs were laid on the 12th.

The immature specimen (which was numbered 8), received on the 6th., moulted on the 13th. and an adult male came forth.

From this it will be seen that the depositing of eggs begins at once on the completion of the copulatory act, and in two instances at least, copulation was resumed after a portion of the eggs had been deposited. The numbers of eggs from each female were: No. 1, 44; No. 2, 24; No. 3, 43; No. 4, 36; No. 5, 0; No. 6, 20; No. 7, 11.

The times required for the hatching of the eggs were: No. 1, five days; No. 2, six days; No. 3, four days; No. 4, (none hatched); No. 5, (no eggs); No. 6, six days; No. 7, (none hatched). No larvae from these eggs were reared to maturity, and most of them died without coming to the first moult.

The first stage occupied, with the larvae from No. 1, four days; No. 2, three days; No. 3, six days; No. 4, (larvae lived four days without moulting); No. 6, four days.

The second stage occupied, with the larvae of No. 1, seven days; No. 2, seven days.

The third stage occupied, with the larvae of No. 1, eleven days; No. 2, fourteen days.

The immature specimen (No. 8) received on May 6, moulted and became adult on May 13, making seven days' duration for the fifth or last stage.

None of the specimens from St. Vincent gave any figures for the duration of the fourth stage.

Specimens of *D. delauneyi* were received from St. Lucia on April 22, 1905. There were several adult insects but no eggs were produced by them after their arrival, and none of the eggs, found in the box in which they arrived, hatched. The

immature specimens were kept in vials numbered 9 to 20, inclusive. Of these only seven lived to reach the adult condition, and one other moulted three times, but died before becoming adult.

The following table gives particulars as to the fourth larval (pupal) stage of seven specimens received from St. Lucia on April 22. It will be seen that vial No. 17 contained two specimens :—

No.	Date of moulting.	Number of days in fourth stage.	Sex of adult.
9	May 2.	10	Female.
11	„ 3.	11	Male.
13	„ 2.	10	„
17	April 28.	6	„
17	May 4.	12	Female.
18	„ 2.	10	„
19	April 27.	5	„

No. 16 was a larva in the second stage when received. Moults occurred on April 23 and 28, and on May 2, and the insect died on the 6th. without reaching maturity.

Several died without moulting, after varying lengths of time, as follows: eleven days, fourteen days, six days, eleven days, three days.

Of the insects that reached maturity, two pairs were mated: No. 9 (female) and No. 13 (male) in one vial; and No. 11 (male) and No. 17 (female) in a second vial. Nos. 9 and 13 emerged on May 2. On May 5, they were mating, remaining *in coitu* until the 11th., and on the 12th. fifty-three eggs were produced. The male (No. 13) died on the 17th. and the female (No. 9) on the 18th. The eggs laid on the 12th. hatched on the 18th. and the larvae began to moult on the 22nd. The other pair, No. 11 (male) and No. 17 (female), produced no eggs. No. 11 emerged on May 3, and No. 17 on May 4. They were put into a vial together on the 5th. On the 11th., they were *in coitu*, and on the 14th. the male died, and the St. Vincent specimen, No. 8 (male), which emerged on May 13, was put into the vial with No. 17. On May 16 and 17 they were *in coitu*. The male (No. 8) died on the 20th. and the female (No. 17) died on June 7, without producing eggs.

Although no single individual of this species has been reared through the complete life-cycle, an approximation to the length of time required may be made by using the figures already

given for the different stages in the lives of different individuals. The following is a summary of these figures :—

Length of time in the egg	... ...	4 to 6 days
" " " 1st. stage	... ...	3 " 6 "
" " " 2nd. "	... ...	4 " 7 "
" " " 3rd. "	... ...	11 " 14 "
" " " 4th. "	... ...	10 " 12 "
" " from becoming adult to egg laying	... ...	10 days.

From these figures it would appear that the life-cycle of *D. delauneyi* occupies from forty-two to fifty-five days.

D. howardi.—Specimens of this species were received from Trinidad, on January 30, 1905. All the insects were dead, but fourteen eggs were found in the box in which they had been sent. The eggs hatched on February 3. Further specimens were received on May 6, and, as in the previous instance, the insects were dead, and several eggs which had been laid previous to this date were found in the box. These eggs hatched on the 11th., and of the insects thus obtained, one was reared to maturity.

The first moult occurred on May 15. The dates of the second and third moults were not recorded. The fourth moult occurred on June 6, and the fifth on the 21st. ; the insect on this date becoming an adult male.

In this instance the life-cycle occupied a period of about forty-seven days, divided between the different stages as follows : egg stage, about six days ; first larval stage, four days ; second and third larval stages together, twenty-two days ; fourth larval (pupal) stage, fifteen days.

In an article in *Insect Life* (13) Riley and Howard give an account of *Dysdercus suturellus*, H.-Schf., with figures of the adult and of the young in different stages of development. The egg does not seem to have been well known at that time, and the eggs figured, although at first supposed to be of this species, proved not to belong to the cotton stainers. A brief description of the egg of *D. suturellus* is quoted from Hubbard (11) : 'The eggs are oval in shape, amber coloured, with a pearly lustre, and present, under the lens, a pattern of closely reticulated lines.'

The eggs of *D. delauneyi* are ovoid in shape ranging in length from 1·2 to 1·3 mm. in St. Vincent specimens, and in width from 0·78 to 0·84 mm.

The eggs of *D. howardi* are slightly larger, being 1·34 mm. in length.

The colour of the eggs of *D. delauneyi* is a pale cream-white ; those of *D. howardi* being more strongly tinged with cream or yellowish.

When first deposited, the eggs of these species are moist and slightly sticky, but when dry they are hard and resilient. They do not cohere in masses nor do they strongly adhere to any surface on which they may be laid, and, if found attached, are very easily loosened.

The eggs of *D. andreae* and *D. delauneyi* have been found in the open cotton bolls in the field, and amongst cotton seed in and about the gin houses. In captivity the female apparently makes no choice of place for depositing her eggs, which seem most frequently to be scattered about indiscriminately.

In the Bahamas, Schwartz (7) states that he was informed by the natives that the cotton stainers (*D. suturellus*) deposited their eggs in the crevices of the rocks; Lefroy (34) states that the eggs of *D. cingulatus* in India 'are laid in a loose mass under the surface of the soil, usually in a crack or depression, which the female covers with earth after depositing the eggs,' and (35) 'that the female lays a mass of little round yellow eggs on the soil or on the cotton boll.'

Hubbard (11) states that the eggs of *D. suturellus* 'in winter, at least, and around gin houses, are dropped loosely in the sand and among the heaps of cotton seed upon which the bugs are feeding.'

FOOD PLANTS.

The species of *Dysdercus* are known chiefly as pests on cotton, which seems to be the preferred food. In addition to cotton, the West Indian species feed upon the seeds of the silk-cotton tree (*Eriodendron anfractuosum*), on okra (*Hibiscus esculentus*), on musk (*Hibiscus Abelmoschus*), and probably on other malvaceous plants; perhaps also on plants of other orders, although actual observations are wanting on this point.

In captivity in the laboratory of the Imperial Department of Agriculture, cotton stainers have been fed on cotton seed, portions of unripe cotton bolls, bits of sugar-cane, and pieces of banana. It is interesting to note that when fed on sections of young cotton bolls, the stainers, old and young, insert the proboscis into the soft fibre, and very rarely attack the seed. This has been observed many times, with bolls at different stages of development, from very young pods (in which the embryos were merely a soft mucilaginous mass and the fibre just beginning to develop) to ripe bolls. The seed is rarely attacked in these cases, the fibre being much preferred. The pod seemed to be the second choice, and the seed the last. When the seed was fed upon, the proboscis was inserted into the shell (testa) and it was not observed that the inside of the seed was attacked, except in rare instances. When cotton leaves were put into the cages with the stainers they were fed upon, but the stainers did not appear to do so well on them as on the young bolls. The sugar-cane and banana were readily eaten. Although the cotton stainers are known to feed on the ripe cotton seed about the gin houses, they would not do this in the laboratory, nor would they feed on the seeds of the silk-cotton.

In the St. Vincent Botanic Gardens, *D. delauneyi* was observed to be feeding in great numbers on the seeds of silk-cotton. Many of these insects attack a single seed, so that frequently only a mass of insects can be seen, the seed being entirely covered by them. So firmly do they insert the proboscis into the seed that a single insect is able to drag a seed along

the ground, and, in one instance, the writer saw a specimen on the bark of a tree trunk several inches from the ground with its beak firmly fixed to a silk-cotton seed. The stainer must have climbed backwards up the tree trunk, and when discovered, stood, head downward, with the seed suspended at the tip of the rostrum.

D. suturellus is recorded by Hubbard (11) as a pest of oranges in Florida. He says: 'At first only adults are seen; these at once attack the fruit upon the trees. A week or ten days later, the wingless young appear, always upon the ground, clustering upon the fallen fruit. If the trees are not stripped and the fruit harvested before the young brood become adult and acquire wings, the entire crop will be lost. Even the packing-house is not safe from invasion, and fruit is apt to be destroyed after it has been gathered and stored in the bins.

'In puncturing the orange, the bugs insert their slender sucking beak, often its entire length, and although the oil of the rind forms their principal food, they nevertheless frequently regale themselves with draughts of juice from the pulp within, and are sometimes seen to suck the juices from the surface of split or injured fruit, tapping it with the tips of their proboscis, after the manner of flies.

'The sucking-tube, having the fineness of a hair, leaves no visible wound upon the outside of the fruit, and no indication of its passage within. An orange which has been attacked, therefore, shows no outward sign of injury; nevertheless, a single puncture causes it to drop in a few hours from the tree, and to decay in one or two days.

'It is quite useless to pack for shipment to a distance the fruit from a grove which is attacked by red bugs, since the unsound fruit decays in the packages and soon ruins the whole.'

Riley and Howard (13) state that at that time [1889] the cotton stainer (*D. suturellus*) damaged no cultivated crop except cotton and oranges, but Professor Comstock is stated to have 'found it in the winter of 1879 upon a native species of Rose Mallow (*Hibiscus* sp.), and also upon an introduced species, which he called *Hibiscus fulgidus*, at Maitland, Florida. He also found it on the leaves of guava which were infested by a mealy bug, but was unable to determine whether the cotton stainers were feeding upon the leaves of the plant or upon the sweet excretion of the mealy bug. According to the Rev. W. F. Nigels, of Demedin, Florida, it is also found on what is there termed Spanish Cocklebur (*Urena lobata*) and upon the poisonous nightshade (*Solanum nigrum*), but this statement has not been confirmed by other observers.'

Quaintance (21) states that *D. suturellus* attacks the egg plant (*Solanum Melongena*).

Howard (23) states that a correspondent in Florida has found this insect (*D. suturellus*) abundant and destructive upon certain tangerine orange trees during December 1897. He found it also puncturing rose buds and blossoms, the seed pods

of the Jamaica Indian sorrel (*Hibiscus Sabdariffa*), the pods and blossoms of the oleander, and the ripe fruit of the tropical or melon papaw (*Carica Papaya*).

Lefroy (34) states that in addition to cotton, the red cotton bug (*Dysdercus cingulatus*) attacks the 'bhinda' (*Hibiscus esculentus*), and that it has been reported as attacking the flowers of hibiscus (? *H. vitifolius*) at the Saharanpore Botanical Gardens.

DAMAGE TO COTTON.

In the West Indies, there seems to be a considerable difference of opinion as to the amount of damage caused by cotton stainers. Planters believe that these insects injure the young bolls by puncturing them and sucking the juice, and that they injure the fibre by staining it; but they do not seem to have estimated the loss from this cause, either in the amount of the crop or in the reduced value of the stained cotton. It cannot, however, be doubted that the presence of large numbers of these insects in cotton fields causes a considerable decrease in the amount and value of the crop.

Just what the nature of the injury is, however, it is difficult to say, and the whole question of the nature and amount of the injury to the cotton plant, seed, and fibre might well form the subject of an extended investigation.

The writer of this article believes that cotton stainers injure cotton in the following ways:—

(1) By sucking the sap from tender parts of the plant, they reduce its vitality, and thus lessen the quantity of the yield and possibly affect the quality of the fibre.

(2) By sucking the sap from the pod they probably cause a certain amount of drying-up or shrivelling of the pod, i.e., the carpels, and thus tend to increase the number of abortive bolls which never open fully, and which do not produce first-class cotton.

(3) The cotton stainers are frequently to be found within the bracts at the base of the pod. By sucking the juice from the fleshy stalk of the pod, while it is still very young, they probably check the growth of the pod and of the cotton inside it.

(4) The eggs of the cotton stainer are sometimes laid in the newly opened boll, and such bolls are frequently found to contain enormous numbers of young stainers. In the event of the attack on the moist fibre and tender seed beginning immediately on the opening of the pod, it is likely that the quality of the fibre and the vitality of the seed for planting purposes may be affected. It seems likely that most of the staining of the fibre is also done by the larvae.

(5) Cotton stainers are often to be found in seed-cotton and upon cotton seed, but they probably do not cause much injury at this time. If caught in the gins and crushed, they impart a stain to the cotton, and this seriously affects its value.

Positive statements are made as to the great injury caused to the cotton industry in other places by these pests. Schwartz (7) classes the cotton stainer as the most formidable enemy of cotton in the Bahamas, 'an enemy which makes the continuance of cotton cultivation in the Bahamas very questionable. The damage done by this insect is enormous; it destroys regularly the entire summer crop, i.e., that picked in January, and destroys half or more of the second crop.'

Saunders (10) speaks of the cotton stainer (*D. suturellus*) 'as one of the worst pests with which the cotton planters of Florida and the West Indies have to contend.'

Glover (3) is quoted by Riley and Howard (13) as follows:—

'It drains the sap from the bolls by its puncture, causing them to become diminutive or abortive; but the principal injury it does is by sucking the juice of the seed and boll and then voiding an excrementitious liquid which stains the cotton fibre yellow or reddish, and very much depreciates its value in the market, the stains being indelible.'

Howard (27) refers to the occurrence of *D. andreae* in Cuba, and states that, although enormous numbers of this species occurred on the young bolls in January and February before the bolls opened, they had no effect on the plant except the dwarfing of the bolls. Toward the end of March, however, when the picking had been nearly finished, the stainers attacked the fibre remaining in the field, and stained it badly.

Howard (25) records the occurrence of a cotton stainer (*D. ruficollis*) in Peru, which is stated to injure cotton to the extent of 4c. to 6c. per ℔. 'During 1898 the damage to two cotton plantations at Paita from this insect was at least $10,000.'

Lefroy (35) is of opinion that the damage to the seed is considerable. He says 'a seed that has been sucked out shows no mark, looks normal, and can be distinguished only when cut open. Such a seed will not germinate, yields no oil, and is valueless.'

DAMAGE TO CROPS OTHER THAN COTTON.

The orange appears to be the only crop other than cotton that has suffered severely from attacks of cotton stainers. This damage has been confined to Florida, and has also been caused by one species (*D. suturellus*).

Although he records this insect as attacking the egg plant, Quaintance (21) does not state how serious a pest it has been. Comstock (8), Hubbard (11), and Riley and Howard (13), all speak of the seriousness of the attacks of this insect on the orange.

REMEDIES.

Although cotton stainers have been known as pests for many years, not much has been done in developing insecticides or control measures for dealing with them.

In the West Indies two methods have been used with success. One of these consists of attracting the insects to baits, and killing them with hot water or kerosene. Cotton seed or pieces of sugar-cane, placed in small heaps at frequent intervals throughout the field, have been used for bait. Cotton seed seems to be much preferred to sugar-cane, and, scattered about the ginneries, it attracts large numbers of these insects, and may be made to serve as a trap (28, 29, 31). This method is likely to give best results 'between crops' when there is not much attraction for the insects on the plants.

During the flowering and ripening period, however, the practice of collecting is likely to give the best results in controlling these pests. At this time the insects, young and old, are to be found on the cotton plants, and are frequently congregated on the bolls and tips of branches. The method of collecting (29) is this—a bucket or kerosene tin, containing a small amount of water and kerosene, is used for catching the insects, which are shaken or jarred off into it, the film of kerosene killing them quickly. The process has been tried in certain of the West India Islands, and has been reported to be economical and fairly effective, keeping the stainers under control at a small cost, although many insects escape the collecting tin.

Schwartz (7) states that in the Bahamas 'in slavery times, the slaves were "taxed" to collect by hand every day, a quart of these bugs. At the present time [1879] their habit of crowding during the hot hours of the day under the dead leaves upon the ground gives the natives a way to destroy them in large numbers. Dry leaves, twigs, etc., are placed in suitable places protected from the sun, and set on fire at noon; or still better, a few cotton seeds are thrown into such heaps of dry débris and attract vast numbers of such insects.'

NATURAL ENEMIES.

The cotton stainers appear to be remarkably exempt from the attacks of natural enemies. The writer has observed in a cotton field in Montserrat an adult lady-bird (*Megilla maculata*, var.) eating a young larva of *D. andreae*. This is the only instance that has come under personal observation, and in the bibliography cited at the end of this article, there seems to be no record of any predaceous or parasitic enemy of the cotton stainers.

Hubbard (11) states that the red bug (*D. suturellus*) 'is not eaten by fowls or other birds, nor has any enemy of its own class been hitherto observed to attack it. The eggs will probably be found to have parasites, as is the case with most other Hemiptera, but none have as yet been discovered.'

Although large numbers of eggs of *D. delauneyi*, *D. andreae*, and *D. howardi* have been under observation at the laboratory of the Imperial Department of Agriculture during the past two years, no parasites have been observed, nor have any of the eggs shown the appearance of being parasitized.

GEOGRAPHICAL DISTRIBUTION.

The following table shows the distribution of the species of *Dysdercus* in tropical and subtropical America:—

TABLE I.

Distribution of American Species of Dysdercus.

1. *albidiventris*	...California, Texas, Mexico, Guatemala, Nicaragua.
2. *andreae* (syn. suturalis, Fab.)	...Cuba, Jamaica, San Domingo, St. John (Virgin Islands), St. Kitt's-Nevis, Antigua, Montserrat, Guadeloupe.
3. *annuliger* (see delauneyi)	...
4. *annulis*	...
5. *chiriquinus*	...Panama.
6. *concinnus*	...Mexico, Guatemala, British Honduras, Nicaragua, Panama.
7. *delauneyi* (syn. annuliger)	...Montserrat, Guadeloupe, Dominica, Martinique, St. Lucia, Barbados, St. Vincent, Grenadines, Grenada.
8. *fervens*	...Hayti, San Domingo.
9. *flavolimbatus*	...Mexico, Guatemala, Costa Rica.
10. *incertus*	...Costa Rica.
11. *jamaicensis*	...Jamaica.
12. *longirostris*	...Brazil.
13. *mimus*	...Texas, Mexico, Guatemala, Costa Rica, Cuba.
14. *mundus*	...British Honduras.
15. *obliquus*	...Mexico, Guatemala, Panama.
16. *ochreatus*	...North America, Georgia.
17. *oncopeltus*	...Panama.
18. *peruvianus*	...
19. *ruficeps*	...
20. *ruficollis*	...Mexico to Brazil, Peru.
21. *rufipes*	...Columbia.
22. *rusticus*	...Columbia.
23. *sanguinarius*	...Cuba.
24. *splendidus*	...Panama.
25. *suturellus* (suturalis, Burm.)	...South Carolina, Georgia, Alabama, Florida, Bahamas, Cuba, Porto Rico, Bahia (Brazil).

To this list should be added the two new species and the new variety described in this paper:—

26. *fernaldi*	...Grenada.
27. *howardi*	...Trinidad, Tobago.
28. *howardi*, var. *minor*	...Trinidad.

TABLE II.

American Localities in which Species of Dysdercus occur.

UNITED STATES :—

Texas, *albidiventris, mimus.*
California, *albidiventris.*
Georgia, *suturellus, ochreatus.*
Florida, *suturellus.*
Alabama, *suturellus.*
South Carolina, *suturellus.*

MEXICO :—

albidiventris, ruficollis, concinnus, flavolimbatus, mimus, obliquus.

CENTRAL AMERICA :—

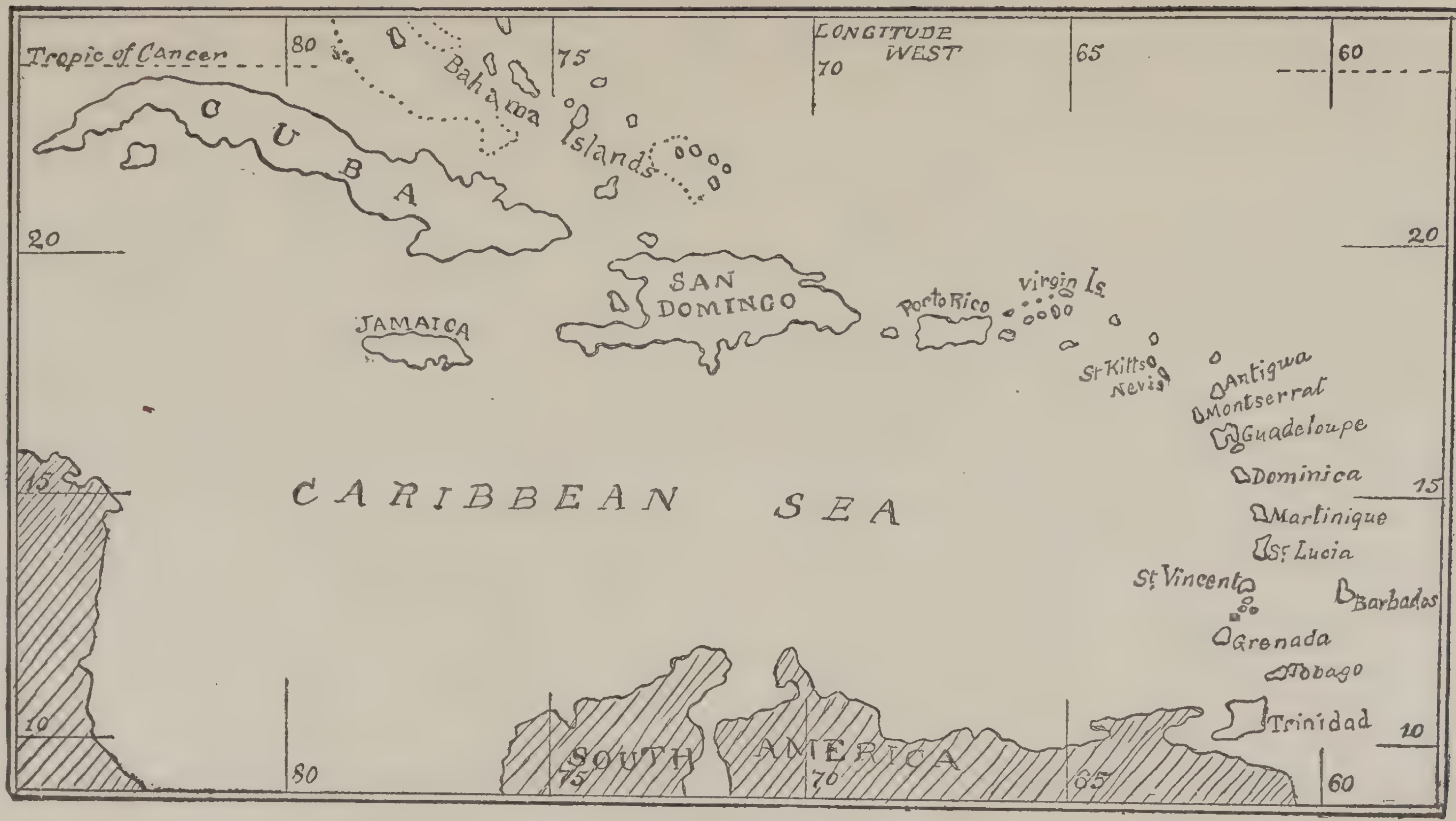
Guatemala, *albidiventris, concinnus, flavolimbatus, mimus, obliquus.*
British Honduras, *concinnus, mundus.*
Nicaragua, *albidiventris, concinnus.*
Costa Rica, *flavolimbatus, incertus, mimus.*
Panama, *chiriquinus, concinnus, obliquus, oncopeltus, splendidus.*

SOUTH AMERICA :—

Brazil, *longirostris, ruficollis, suturellus.*
Columbia, *rufipes, rusticus.*
Peru, *ruficollis.*

WEST INDIES :—

Bahamas, *suturellus.*
Cuba, *andreae, mimus, sanguinarius, suturellus.*
Jamaica, *andreae, jamaicensis.*
Hayti, *fervens.*
San Domingo, *fervens, andreae.*
Porto Rico, *suturellus.*
St. John (Virgin Islands), *andreae.*
St. Kitt's-Nevis, *andreae.*
Antigua, *andreae.*
Montserrat, *andreae, delauneyi.*
Guadeloupe, *andreae, delauneyi.*
Dominica, *delauneyi.*
Martinique, *delauneyi.*
St. Lucia, *delauneyi.*
Barbados, *delauneyi.*
St. Vincent, *delauneyi.*
Grenadines, *delauneyi.*
Grenada, *delauneyi, fernaldi.*
Trinidad, *howardi, howardi,* var. *minor.*
Tobago, *howardi.*



Sketch Map of the West Indies.

From the preceding tables it will be seen that the genus *Dysdercus* presents some peculiar conditions in geographical distribution. *D. suturellus*, which is found in the Southern United States, is reported to occur in the Bahamas, Cuba, and Bahia (Brazil). Schwartz (7) does not give the name of the cotton stainer which he found in the Bahamas; but Riley and Howard (13) mention *D. suturellus* as occurring in the United States, Cuba, and the Bahamas. Riley (12) [Appendix, pp. 63-4] gives a list of cotton insects from Bahia sent by Mr. R. A. Edes, United State Consul, January 21, 1880, among which is 'one cotton bug.' On page 121 of the Appendix will be found notes on these specimens which include the statement: 'The large bug is the cotton stainer (*Dysdercus suturellus*, H-Schf.), also found in the United States and greatly injurious to cotton on the Bahamas.'

That this species is still troublesome in the Bahamas will be seen from the following sentence which is taken from a letter, dated March 30, 1906, from Mr. W. N. Cunningham, Curator of the Botanic Station, Nassau, to the Imperial Commissioner of Agriculture: 'I may say that the cotton stainers (*Dysdercus suturellus*) were on the plants in large numbers.' Professor O. W. Barrett, then Entomologist and Botanist to the Porto Rico Experiment Station, in a letter dated November 16, 1904, to the writer of this article, states: 'We have *Dysdercus suturellus*, and perhaps other species.'

Riley and Howard (13) state that the cotton stainer of the United States (*D. suturellus*) is a native of tropical America and the West Indies. Its occurrence in the Bahamas and Cuba is mentioned. They also state: 'We have no knowledge, however, of its occurrence in South America.' This was written in 1889, whereas Mr. Edes' specimen was identified as *D. suturellus* in 1880.

Either the record in the Fourth Report of the Entomological Record, of the occurrence of *D. suturellus* in Bahia, was overlooked in the preparation of the article in *Insect Life* (13), or further material from Bahia had proved in the meantime that the specimen from the latter place was not *D. suturellus* as at first determined. This species will be seen to have a remarkable distribution in that it seems not to occur between Cuba and Porto Rico and Bahia in Brazil.

D. ruficollis is also remarkable in this respect. Lethierry and Severin (17) give its distribution 'from Brazil to Mexico,' and Howard (25) records its occurrence in Peru.

The distribution of these species appears the more striking when compared with others given in these tables. In many instances only one locality is known for each species, and most of the others occur only in a few adjoining countries or islands.

That *D. andreae* has long been established in the West Indies is shown by the reference to it by Sir Hans Sloane in *Natural History of Jamaica*, 1725, Vol. II, p. 203, as a 'cimex of a scarlet colour with a white St. Andrew's cross on its back.

This is one-third part of an inch in length. It is very often to be met with amongst flowers.'

The distribution of *D. andreae* and *D. delauneyi* furnish good illustrations of localization, or consecutive distribution. Reference to the foregoing table shows that *D. andreae* is recorded from the Greater and the Lesser Antilles, and that it occurs in an unbroken series, with the exception of Porto Rico, from Cuba, its northern and western limit, to Montserrat, its southern and eastern limit ; while from the Virgin Islands (St. John) to Montserrat it is the only species recorded from any of the islands.

D. andreae is distributed through a chain of islands extending some 1,600 miles, and for about 260 miles of that distance it is the only species of the genus that has been recorded, with the exception of the last two islands to the eastward of its range, where it meets *D. delauneyi.*

D. delauneyi occurs in a chain of islands extending about 370 miles, and is the only species of the genus known in that distance except in the two islands at the northern and one at the southern limit of its range.

Montserrat and Guadeloupe are shown to have both *D. andreae* and *D. delauneyi*, while from Dominica to the Grenadines only one species, *D. delauneyi*, occurs in each locality. In Grenada, *D. fernaldi* and *D. delauneyi* occur, and in Trinidad *D. howardi* and its variety *minor* ; while in Tobago only *D. howardi* is known.

It may be mentioned that in Montserrat, *D. delauneyi* is very rare, *D. andreae* being the prevailing species ; while in Grenada *D. delauneyi* prevails and *D. fernaldi* is rare.

The change from *andreae* to *delauneyi* is very abrupt. Only two islands are common to them, and the difference in appearance is very striking. *D. andreae* is conspicuous by its white body markings and general sharp delineations of colour. In this species, the white prothoracic collar with its delicate black border behind, the white St. Andrew's cross on the back, the fine white line on the posterior margin of the pronotum, bordered anteriorly with black, and the black spots in the inner angles of the hemi-elytra, together with the bright white margins of the segments of thorax and abdomen are all noticeable at a glance.

D. delauneyi, on the other hand, is wanting in all these, the only striking and unvarying colour characteristics being the white ring at the base of the apical segment of the antennae. There are no delicate markings. The sanguineous or ferruginous ground colour merges with the black, or is suffused with it, and the variations in colour are merely the result of the running together of these two colours to a greater or less degree. The body segments are generally margined with black, but this is not a delicate and definite line, as is the white line in a similar place in *D. andreae.*

Seen from above, *D. delauneyi* presents a pattern of reddish and black ; but the amount, the distribution, and the intensity of these colours vary considerably.

The change from *D. delauneyi* to *D. fernaldi* in Grenada is not so great, one point in colour marking being constant: that is the white ring at the base of the apicial segment of the antennae. The colour pattern in *D. fernaldi*, as seen from above, is much more definite than that of *D. delauneyi*. The hemielytra and membrane are sharply defined in their colour. The pale prothoracic collar with its fine border of black behind, the distinct black margins on the ventral segments, and the pale or whitish margins on the thoracic segments show a more constant and delicate pattern than the markings of *D. delauneyi*, and partake somewhat of the character of the markings of *D. andreae*.

D. howardi, and its variety *minor*, on the other hand, while showing in markings and pattern distinct relationship to *D. fernaldi* and *D. andreae*, show also the tendency, already noted in *D. delauneyi*, of the black to suffuse through the lighter colours.

In this species and in the variety, the white basal ring on the apical segment of the antennae is distinctly to be seen, as in *fernaldi* and *delauneyi*. The prothoracic collar, however, like that of *andreae*, is white, with a delicate, black, posterior border. The silvery-white fasciae on the thoracic segments, and the black margins on the ventral segments are well defined and constant. The tendency of the black to suffuse through the yellowish is to be noticed in the hemi-elytra and the pronotum.

In British Guiana, Beckett (33) records a cotton stainer (*Dysdercus* sp.) which 'can readily be distinguished by a dirty whitish cross, with two dark patches on the back.' Lefroy (34, 35) records *D. cingulatus* in India. Riley (12) [chap. iv, p. 39] mentions 'a red bug allied to *Dysdercus suturellus* of the West Indies' as occurring in Australia.

Mr. F. V. Theobald at the conference of Economic Biologists at Liverpool University early in the present year reported three species of cotton stainers from Uganda, one of which is new to science.

Specimens of *D. andreae* and *D. delauneyi*, as well as type specimens of *D. fernaldi*, *D. howardi*, and *D. howardi*, var. *minor* will be sent to the British Museum (Natural History) and to the United States National Museum.

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INSECTS AS CARRIERS OF DISEASE.

The following paper is taken from an address delivered at the meeting of the British Association for the Advancement of Science at Pretoria in 1905, by Mr. A. E. Shipley, M.A., F.R.S., Lecturer in Advanced Morphology of the Invertebrata, Cambridge University, and has been reprinted from *Nature* for January 4, 1906, and contains all the latest information about parasitic diseases, especially those of man

As it was read in South Africa, particular stress is laid upon many of those diseases common there. Some of these diseases are well known in the West Indies, and therefore, the footnotes, added by Mr. H. A. Ballou, B.Sc., Entomologist on the staff of the Imperial Department of Agriculture for the West Indies, on the distribution of the insects that cause these diseases throughout the West India Islands should be of considerable interest :—

The last few years are marked in the annals of medicine by a great increase in our knowledge of certain parasitic diseases, and, above all, in our knowledge of the agencies by which the parasites causing the diseases are conveyed.

Chief among these agencies in carrying the disease-causing organisms from infected to uninfected animals are the insects, and amongst the insects, above all, the flies. Flies, e.g., the common house-fly (*Musca domestica*), can carry about with them the bacillus of anthrax. Flies, ants, and other even more objectionable insects, are not only capable of disseminating the plague bacillus from man to man, and possibly from rat to man, but they themselves fall victims to the disease and perish in great numbers. They are active agents in the spread of cholera, and the history of the late war in South Africa definitely shows that flies play a large part in carrying the bacilli of enteric fever from sources of infection to the food of man, thus spreading the disease.

The diseases already mentioned are caused by bacteria. Flies also play a part in the conveyance of a large number of organisms which are not bacteria, but which, nevertheless, cause disease.

In considering the part played by flies in disseminating diseases not caused by bacteria, we can neglect all but a very few families, those flies which suck blood having alone any interest in this connexion.

From the point of view of the physician, by far the most important of these families is the Culicidae, with more than 300 described species and five sub-families, of which two, the Culicina and the Anophelina, interest us in relation to disease. The gnats or mosquitos are amongst the most graceful and beautiful insects that we know: but they have been judged by their works and undoubtedly are unpopular, and we shall see that this unpopularity is well deserved.

Gnats belong both to the genus *Culex* and to the genus *Anopheles*. The genus *Culex*, from which the order takes its

name, includes not only our commonest gnat, often seen in swarms on summer evenings, but some 130 other species. Members of this genus convey from man to man the *Filaria nocturna*, one of the causes of the widely-spread disease Filariasis. In patients suffering from this disease, minute embryonic round-worms swarm in the blood-vessels of the skin during the hours of darkness. Between six and seven in the evening they begin to appear in the superficial blood-vessels, and they increase in number until midnight, when they may occur in such numbers that 500 or 600 may be counted in a single drop of blood. After midnight, the swarms begin to lessen, and, by breakfast time, about eight or nine in the morning, except for a few stray revellers, they have disappeared from the superficial circulations, and are hidden away in the larger blood-vessels and in the lungs.

In spite of their incredible number—some authorities place it at 30,000,000 to 40,000,000 in one man—these minute larval organisms, shaped something like a needle pointed at each end, seem to cause little harm. It might be thought that they would traverse the walls of the blood-vessels, and cause trouble in the surrounding tissues; but this is prevented by a curious device. It is well known that, like insects, round-worms from time to time cast their skins, and the young larvae in the blood cast theirs, but do not escape from the inside of this winding-sheet: and thus, though they actively wriggle and coil and uncoil their bodies, their progress is as small, and their struggles as little effective, as are those of a man in a strait-waistcoat.

One reason of the normal appearance of the creatures in the blood at night is undoubtedly connected with the habits of its second host, the gnat or mosquito. Two species are accused of carrying the *Filaria* from man to man—*Culex fatigans** and *Anopheles nigerrimus*. Sucked up with the blood, the round-worms pass into the stomach of the insect. Here they appear to become violently excited, and rush from one end to the other of their enveloping sheath, until they succeed in breaking through it. When free, they pierce the walls of the stomach of the mosquito, and come to rest in the great thoracic muscles, remaining here for some two or three weeks, growing considerably, and developing a mouth and an alimentary canal; thence, when they are sufficiently developed, they make their way to the proboscis of the mosquito. Here they lie in couples. Exactly how they effect their entrance into man has not yet been accurately observed; but presumably it is during the process of biting. Once inside man, they work their way to the lymphatics, and very soon the female begins to pour into the lymph a stream of young embryos, which reach the blood-vessels through the thoracic duct. It is, however, the adults, which are the source of all the trouble. They are of considerable size, 3 or 4 inches in length; and their presence, by blocking channels of the lymphatics, gives rise to a wide range of disease, of which Elephantiasis is the most pronounced form.

**Culex fatigans* is the common brown mosquito of the West Indies. It is most troublesome at night and in the wet season.

We now pass to the second of the diseases carried by gnats, that of Malaria.

The parasite which causes malaria is a much more lowly organized animal than the *Filaria*. It is named *Hæmamœba*, and it, too, is conveyed by an insect, and, so far as we know, by one genus of mosquito only, the *Anopheles*. Hence, from the point of view of malaria, it is important to know whether a district is infected with *Culex* or *Anopheles*. The former is rather humpbacked and keeps its body parallel with the surface it is biting, and its larva hangs at an angle below the surface of the water by means of a respiratory tube. *Anopheles*,* on the other hand, carries its body at a sharp angle with the surface upon which it rests, and its larva lies flat below the surface-film and parallel with it. The malarial parasite lives in the blood-cells of man, but at a certain period it breaks up into spores which escape into the fluid of the blood, and it is at this moment that the sufferer feels the access of fever. Their presence and growth within the blood-cells result in the destruction of the latter, a very serious thing to the patient if the organisms be at all numerous. If the spores be sucked up by an *Anopheles*, they undergo a complex change, and ultimately reproduce an incredible number of minute spores or sporozoites, each capable of infecting man again if it can but win entrance into his body.

In normal circumstances, for each larva which enters a mosquito one *Filaria* issues forth, longer, it is true, and more highly developed, but not much changed. The malaria parasite undergoes, in its passage through the body of the *Anopheles*, many and varied phases of its life-history.

Whoever has watched under a lens the process of 'biting,' as carried on by a mosquito, must have observed the fleshy proboscis (labium) terminating in a couple of lobes. The labium is grooved like a gutter, and in the groove lie five piercing stylets, and a second groove or labrum. It is along this labrum that the blood is sucked. Between the paired lobes of the labium, and guided by them (as a billiard cue may be guided by two fingers), a bundle of five extremely fine stylets sinks slowly through the epidermis, cutting into the skin quite easily. Four of these stylets are toothed, but the single median one is shaped like a two-edged sword. Along its centre, where it is thickest, runs an extremely minute groove, only visible under a high power of the microscope. Down this groove flows the saliva, charged with the spores or germs of the malaria-causing parasite. Through this minute groove has flowed the fluid which, it is no exaggeration to say, has changed the face of continents and profoundly affected the fate of nations.

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*Several species of *Anopheles* occur in the West Indies, but, strangely, none have been found in Barbados, and as a consequence malaria is not known to exist in that island. Patients suffering from malaria visit Barbados from other parts of the American tropics, and there would be plenty of opportunity for infection if a malaria-carrying mosquito were present. The so-called fever-and-ague common in Barbados is not a malarial disease, but a manifestation of filaria.

It is an interesting fact that, amongst the Culicidae, it is the female alone that bites, and she is undoubtedly greedy. If undisturbed, she simply gorges herself until every joint of her chitinous armour is stretched to the cracking point. At times even what she takes in at one end runs out at the other. But she never ceases sucking. The great majority of individuals, however, can never taste blood, and subsist mainly on vegetable juices.

Anopheles is often conveyed great distances by the wind, or in railway trains or ships; but of itself it does not fly far, about 500 or 600 yards—some authorities place it much lower—is its limit. Both *Anopheles* and *Culex* lay their eggs, as is well known, in standing water, and here three out of the four stages in their life-history—the egg, the larva, and the pupa—are passed through. The larva and the pupa hang on to the surface-film of the water by means of certain suspensory hairs, and by their breathing apparatus. Anything which prevents the breathing tubes reaching the air ensures the death of the larva and pupa. Hence the use of paraffin on the pools or breeding places. It, or any other oily fluid, spreads as a thin layer over the surface of the pools and puddles, and clogs the respiratory pores, and the larvae or pupa soon die of suffocation.

Thus a considerable degree of success has attended the efforts of the sanitary authorities, largely at the instigation of Major Ross, all over the world, to diminish the mosquito plague. It is, of course, equally important to try and destroy the parasite in man by means of quinine. This is, however, a matter of very great difficulty. In Africa, and in the East, nearly all native children are infected with malaria, though they suffer little, and gradually acquire a high degree of immunity. Still, they are always a source of infection, and Europeans living in malarious districts should always place their dwellings to the windward of the native settlements.

Another elegant little gnat, *Stegomyia fasciata*,* closely allied to *Culex*, with which, until recently it was placed is the cause of the spread of that most fatal of epidemic diseases, the yellow fever. Like the *Culex*, but unlike the *Anopheles*, *Stegomyia* has a humpbacked outline, and its larva has a long respiratory tube at an angle to its body, from which it hangs suspended from the surface-film of its watery home. It is a very widely distributed creature; it girdles the earth between the tropics, and is said to live well on shipboard. It breeds in almost any standing fresh water, provided it is not brackish. The female is said to be most active during the warmer hours of the day, from noon until three or so, and in some of the West Indies it is known as the 'day-mosquito.'

The organism which causes yellow fever has yet to be found. It seems that it is not a bacterium, and that it lives in

* *Stegomyia fasciata* has a very general distribution throughout the West Indies. It is, in many places, the common day mosquito and is known as the 'Scots grey.'

the blood of man. It evidently passes through a definite series of changes in the mosquito, for freshly infected mosquitos do not at once convey the disease. After biting an infected person, it takes twelve days for the unknown organism to develop in the *Stegomyia*, before it is ready for a change of host. The mosquitos are then capable of inoculating man with the disease for nearly two months. The period during which a man may infect the mosquito, should it bite him, is far shorter, and extends only over the first three days of the illness.

Very careful search has hitherto failed to reveal the presence of the parasite of yellow fever. By its works alone can it be judged. It seems that, like the germ of rinderpest and of foot-and-mouth disease, it is ultramicroscopic ; and our highest lenses fail to resolve it.

Of the great obstacles, which have for generations succeeded in keeping the great continent of Africa, except at the fringes, comparatively free from immigrants, three, and these by no means the least important, are insignificant members of the order Diptera. We have considered the case of *Culex* and *Anopheles*. The third fly, we have now to do with, is the Tse-tse fly (*Glossina morsitans*), which communicates fatal diseases to man, and to cattle and domesticated animals of all kinds.

The members of the genus *Glossina* are unattractive insects, a little larger than our common house-fly, with a sober brownish or brownish-grey coloration. When at rest the two wings are completely superimposed, like the blades of a shut pair of scissors ; and this feature readily serves to distinguish the genus from that of all other blood-sucking flies, and is of great use in discriminating between the Tse-tse and the somewhat nearly allied *Stomoxys* and *Hæmatopota*.

The Tse-tse flies rapidly and directly to the object it seeks, and must have a keen sense of smell, or sight, or both, making straight for its prey, and being most persistent in its attacks. The buzzing, which it produces when flying, is peculiar, and easily recognized again when once heard. After feeding, the fly emits a higher note, a fact recalling the observation of Dr. Nuttall and the present writer on the note of *Anopheles*, in which animal we observed that 'the larger the meal the higher the note.' The Tse-tse does not settle lightly and imperceptibly on the sufferer as the Culicidae do, nor does it alight slowly and circumspectly after the manner of the horse-flies, but it comes down with a bump, square on its legs. Like the mosquito, the Tse-tse is greedy, and sucks voraciously. The abdomen becomes almost spherical, and of a crimson red. Unlike so many of the blood-sucking Diptera, in which the habit is confined to the females, both sexes of *Glossina* attack warm-blooded creatures.

The fly always seems to choose a very inaccessible portion of the body to operate on, between the shoulders in man, or on the back and belly in cattle and horses, even inside the nostrils in the latter, or on the forehead in dogs. According to Lieut.-Colonel D. Bruce, C.B., R.A.M.C., to whom we owe so much

of our knowledge of this fly and its evil work, the female does not lay eggs, but is viviparous, and produces a large, active, yellow larva, which immediately crawls away to some secluded crevice, and straightway turns into a hard, black pupa, from which the imago emerges in some six weeks. Thus two stages, the egg and the larva, both peculiarly liable to destruction, are practically skipped in the Tse-tse, at any rate in some species.

The genera of the Culicidae which we have considered are found practically all over the world, but the genus *Glossina* is, fortunately, confined to Africa. From the admirable map of the geographical distribution of the fly compiled by Mr. Austen, we gather that its northern limit corresponds with a line drawn from the Gambia, through Lake Chad to Somaliland, somewhere about the thirteenth parallel of north latitude. Its southern limit is about on a level with the northern limit of Zululand. The Tse-tse, of course, is not found everywhere within this area; and, though it has probably escaped observation in many districts, it seems clear that it is very sporadically distributed.

Even where the Tse-tse is found, it is not uniformly distributed, but occurs in certain localities only. These form the much dreaded 'fly-belts.' The normal prey of the fly is undoubtedly the big game of Africa. But they are not the only factor in its distribution. The nature of the land also plays a part. There are the usual discrepancies in the accounts of travellers, especially of African travellers, as to the exact localities the *Glossina* affects; but most writers agree that the Tse-tse is not found in the open veldt. It must have cover. Warm, moist, steamy hollows, containing water and clothed with forest growth, are the haunts chosen.

The Tse-tse fly belongs to the family Muscidae, the true flies, a very large family, which also includes our house-fly, blue-bottle fly, etc. These flies, unlike *Anopheles* and *Culex*, are day-flies, and begin to disappear at or about sunset.

The practical disappearance as the temperature drops has enabled the South African traveller to traverse the fly-belts with impunity during the cooler hours of the night. At nightfall the Tse-tse seems to retire to rest amongst the shrubs and undergrowth; but, if the weather be warm, it may sit up late; and some experienced travellers refrain from entering a fly-belt, especially on a summer's night, until the temperature has considerably fallen.

The sickness and death of the cattle bitten by the Tse-tse were formerly attributed to some specific poison secreted by the fly, and injected during the process of biting. It is now, largely owing to the researches of Colonel Bruce, known to be due to the inoculation of the beasts with a minute parasitic organism conveyed from host to host by the fly. The disease is known as 'Nagana,' and the organism that causes it is a species of *Trypanosoma*, a flagellate protozoon or unicellular organism which moves by means of the lashing of a minute, whip-like process. Since Bruce's researches, a number of Trypanosomes have been found causing disease in various

parts of the world; thus *T. evansii* causes the 'surra disease' of cattle, horses, and camels in India; *T. equinum* produces the 'mal de caderas' of the horse ranches of South America; and *T. equiperdum* is responsible for the North African disease, called by the French the 'dourine'; *T. theileri* causes the gall-sickness, and there are others. The particular species of *Trypanosoma* which causes nagana is *T. brucei*, and it does not attack man; goats and donkeys seem also immune; but with these exceptions, all domesticated animals suffer, and in a great percentage of cases the disease terminates in death. Just as the native children in Africa form the source of the supply of the malarial parasite without appearing to suffer much, so do the big game of the country abound in Trypanosomes without appearing to be any the worse. They are in Lankester's phrase 'tolerant' of the parasite, and a harmony between them and the parasite has been established so that both live together without hurting one another. It is from the big game that the disease has spread. In their bodies the harmful effect of the parasite has, through countless generations, become attenuated; but it leaps into full activity again as soon as the Trypanosome wins its way into the body of any introduced cattle, horse, or domesticated animal.

The report of Colonel Bruce, which has just been issued, shows that the sleeping sickness which devastates Central Africa, from the west coast to the east, is also conveyed by a species of Tse-tse fly. Writing more than a hundred years ago of Sierra Leone, Winterbottom mentions the disease. 'The Africans,' he says, 'are very subject to a species of lethargy which they are very much afraid of, as it proves fatal in every instance.' Early last century it was recorded in Brazil and the West Indies; and Lankester has suggested that the deaths which our slave-owning ancestors used to attribute to a severe form of home-sickness, or even to a broken heart, were in reality caused by sleeping sickness. In one year the deaths in the region of Busoga reached a total of 20,000; and it is calculated that, although the disease was only noticed in Uganda for the first time in 1901, by the middle of 1904, 100,000 people had been killed by it. The disease is caused by the presence of a second species of *Trypanosoma* in the blood and in the cerebro-spinal fluid. The existence of this parasite has now been proved in all the cases recently investigated. Apparently the Trypanosome can live in the blood without doing much harm, and only when it reaches the cerebro-spinal canal does it set up the sleeping-sickness. It is also found in great numbers in the lymphatic glands, especially those of the neck, which in patients infected by the parasite are usually swollen and tender. From the similarity of the parasite to that causing the cattle disease of South Africa, the idea at once arose that the Trypanosome was conveyed from man to man by a biting insect. Along the lake shores a species of Tse-tse (*G. palpalis*) abounds: and it was noticed that if the fly, having fed off a sleeping-sickness patient, bit a monkey, the monkey became infected. Further, flies which were captured in a sleeping-sickness district were also capable of conveying the disease to healthy monkeys. The proof

that sleeping sickness is due to a *Trypanosoma*, known as *T. gambiense*, present in the cerebro-spinal fluid of the patient, is due to the brilliant researchs of Colonel Bruce and his colleagues, Captain Grieg and Dr. Nabarro, and that it is conveyed from man to man by *Glossina palpalis*, seems now complete.

Finally, we come to a last class of diseases which is of the utmost interest to the agriculturist and settler, and yet at present is but little understood. These diseases are caused by various species of a protozoon named *Piroplasma*, and the diseases may collectively be spoken of as piroplasmosis. When they are present in cattle they are spoken of in various parts of the world as Texas fever, tick fever, blackwater and red-water. Heartwater in sheep is a form of piroplasmosis. Horses also suffer, and the malignant jaundice or bilious fever which makes it impossible to keep dogs in certain parts of South Africa is also caused by a *Piroplasma*. Finally, under the name of Rocky Mountain fever, spotted or tick fever, the disease attacks man throughout the western half of the United States.

The organisms which cause the disease live for the most part in the red blood corpuscles, but they are sometimes to be found in the plasma or liquid of the blood. Unfortunately, we know comparatively little about the life-history of the *Piroplasma* or of the various stages it passes through, but we do know how it is transmitted from animal to animal and from man to man.

We have seen that the carrier or 'go-between' in the case of the malaria is the mosquito, and in the case of the sleeping sickness is the Tse-tse fly. *Piroplasma*, however, is not conveyed from host to host by any insect, but by mites or ticks—members of the large group of Acarines, which include besides the mites, the spiders, scorpions, harvestmen, and many others.

The ticks differ from the insect bearers of disease, inasmuch as the tick that attacks an ox or a dog does not itself convey the disease, but it lays eggs—for I regret to say here, as with the *Anopheles*, it is the female only that bites and which is infective—and from these eggs arises the generation which is capable of spreading the disease. The tick which conveys the *Piroplasma* from dog to dog is called *Haemophysalis leachi*. The brilliant researches of Mr. Lounsbury have shown that even the young are not immediately capable of giving rise to the disease. The female tick gorges herself with blood, drops to the ground, and begins laying eggs. From these eggs small six-legged larvae emerge. These larvae, if they get a chance, attach themselves to a dog, gorge themselves, and after a couple of days fall off. If their mother was infected they nevertheless do not convey the parasite. After lying for a time upon the ground the larval tick casts its skin and becomes a nymph, a stage roughly corresponding with the chrysalis of a butterfly. This nymph, if it has luck, again attaches itself to the dog and has a meal, but it also fails to infect the dog. After a varying time it also drops to the ground, undergoes a metamorphosis, and gives rise to the eight-legged adult tick. Here at last we reach the infective stage. The adult tick is

alone capable of giving the disease to the animal upon which she feeds, and then only when she is descended from a tick which has bitten an infested host. Think what a life-history this parasite has! Living in the blood corpuscles of a dog, sucked up by an adult tick, passed through her body until it reaches an egg, laid with that egg, being present while the egg segments and slowly develops into the larva; living quiescent during the larval stage and the nymph stage, surviving the metamorphosis, and only leaping into activity when the adult stage is reached. This most remarkable story probably indicates that the *Piroplasma* undergoes a series of changes comparable to those of the malaria organism when it is inside the mosquito. What these stages are we do not at present know, but Dr. Nuttall and Mr. Smedley at Cambridge, and many other observers elsewhere, are at work on the problem, and soon we shall have more light.

With regard to bovine piroplasmosis, Koch and others have distinguished redwater fever, which is conveyed by *Rhipicephalus annulatus*,* and in Europe probably by *Ixodes reduvius*, from the Rhodesian fever which is conveyed by *Rhipicephalus appendiculatus*, and I regret to say by a species dedicated to myself, *Rhipicephalus shipleyi*.

The heartwater disease of sheep and goats is similarly conveyed by *Amblyomma hebraeum*, the Bont tick, and many farmers accuse *Ixodes pilosus* of causing the well-known paralysis from which sheep suffer in the early autumn; and there are many others, diseases such as the chicken disease of Brazil, which is so fatal to poultry yards, and which is conveyed by the *Argas persicus*.†

I will not weary you with more diseases. I think I have said enough to show that within the last few years a flood of light has been thrown upon diseases, not only of man and his domestic animals, but upon such insignificant creatures as the mosquito and the tick. I have tried to show how these diseases interact, and how both hosts are absolutely essential to the disease. We can now to a great extent control these troubles. The old idea that there is something unhealthy in the climate of the tropics is giving way to the idea that the unhealthiness is due to definite organisms conveyed into man by definite biting insects.

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* Cattle ticks occur in the West Indies. *Rhipicephalus* (Boophilus) *annulatus*, the *Piroplasma* carrier, is probably the most common form.

† A species of *Argas*, probably *Argas americanus*, is known in Trinidad and Barbados. No specific disease seems to be attributed to this pest up to the present time. These ticks are very tenacious of life. In March 1904, a piece of wood from a poultry house in Barbados on which a large number of *Argas* ticks were clustered, was received at the Office of the Imperial Department of Agriculture, and placed in a glass jar. About twenty months later, some of the ticks were still alive.

THE SOURCES OF THE NITROGEN OF VEGETATION.

The sources of the nitrogen used by plants as food is a question which has engaged the attention of agricultural chemists for a long period. As soon as it was discovered that nitrogen was a constituent of the plant's substance, speculations as to its source were indulged in. The fact that the atmosphere contains nitrogen to the extent of about four-fifths of its volume, naturally suggested to the minds of early investigators that the air was the source of the plant's nitrogen. It had previously been demonstrated that a plant obtains its carbon from the carbon dioxide present in the air, and, seeing that its proportion is estimated at only 3 parts in 10,000, it might have been expected that an analogy between carbon assimilation and an anticipated nitrogen absorption would receive considerable attention.

As, however, no direct experiments could be brought forward to substantiate this theory, and as, moreover, nitrogen seemed to be a necessary ingredient of all fertile soils, the opinion that the soil was the only source of the plant's nitrogen gradually supplanted the older theory.

The question now arose as to the nature of the nitrogen compounds, which could be absorbed by plants. It was seen from the first that neither plants nor animals were able to produce compounds of nitrogen, which were immediately available as food. Experiments were carried on, which were held to demonstrate the fact that some organic compounds of nitrogen found in the soil are capable of being assimilated. It was also shown that there can be little doubt that plants can absorb some nitrogen in the form of ammonia, of which a small quantity is always found in the soil. The outcome of further experiments has been that, while it is generally allowed that plants can absorb a small quantity of nitrogen in certain organic forms and as ammonia, the principal source of nitrogen is from the nitrates present in the soil.

There is a tendency of all nitrogen compounds in the soil towards conversion into salts of nitric acid. This nitrification has been shown to be due to the action of micro-organic life. This microscopic flora of the soil is roughly classed into fungi and bacteria, but up to the present it has been very inadequately explored. The organisms which have received the chief attention are those concerned with the supply of nitrogen to the plant.

The application to the soil of natural manures, generally produced by the decay of leaves and other parts of plants, is the oldest method of improving the fertility of cultivated land. The turning in of green crops has been used for a large number of years, and has proved very beneficial where the supply of farmyard manure is insufficient. It is therefore seen that, in practice, the fertility of the soil has been maintained or improved by the application of plant material.

Of late years the fertility of the soil has come to be recognized as depending, to a large extent, upon the available

amount of nitrogen for plant absorption. The question therefore arose as to how the complex organic compounds added in the manure could be converted into salts of nitric acid for assimilation. Experiments were conducted which clearly demonstrated that these complex compounds have been broken down into simpler ones through the agency of the soil bacteria. These simpler compounds, in the presence of lime and similar basic substances, are oxidized successively into salts of nitrous and nitric acid, in which form nitrogen is available for the plant.

The fertility of the soil has been shown wholly to depend upon the maintenance of this cycle of 'nitrification' changes, and if it had not been for these bacteria, the often predicted 'nitrogen famine' would have long ago occurred.

The conditions affecting nitrification have been discussed by Mr. H. H. Cousins, M.A., F.C.S., in the *Bulletin of the Jamaica Department of Agriculture* for January 1904, from which a few notes have been reprinted in the *Agricultural News* (Vol. III, p. 110).

For many years it was noticed that cereal crops, produced after a green manuring with leguminous plants, were greater than those after a similar manuring with others. The soil itself, after their growth, contained a much greater amount of nitrogen than could be accounted for by their vegetative parts and roots (*West Indian Bulletin*, Vol. I, p. 212).

It was afterwards found that some micro-organisms are capable of fixing free nitrogen. They take the gaseous element from the air, and, combining it with carbon, hydrogen, and oxygen, form a compound available for higher plants. Such organisms have been found to live in symbiosis with the higher plants, for they generally occupy nodules on their roots.

How the free nitrogen is fixed is a much debated question. In pure cultures the bacteria are able to fix free nitrogen, and therefore it is reasonable to expect that the fixation of this nitrogen by leguminous plants is due to the presence of these bacteria. Recent observations, moreover, show that leguminous crops are unable to grow without the presence of these bacteria.

This is probably the most important discovery that has been made in agricultural science, and one which is likely to bring in a rich return when the process of inoculation of soil devoid of bacteria becomes more general. Allusions to this discovery and its bearing on agricultural practice have already appeared in previous numbers of the *West Indian Bulletin* (Vol. I, p. 396, and Vol. V, p. 241); and in the *Agricultural News* (Vol. II, pp. 77, 94, and Vol. III, p. 358), where the excellent work carried on by the United States Department of Agriculture has been reviewed.

The relation of nitrogen to the plant is therefore a very important one. With the view of presenting a summary of the large amount of experimental work that has been done in this branch of agricultural science, the following paper by

Mr. A. D. Hall, M.A., Director of Rothamsted Experiment Station, has been reprinted from *The Book of the Rothamsted Experiments*:—

To arrive at a proper understanding of the scheme of the Rothamsted experiments it is necessary to reconstruct a little the state of the knowledge of agricultural science at the time they were begun in 1843. In many respects it was a period of considerable activity in matters agricultural; the whole landed interest were making great efforts towards the improvement of land and stock and of methods of cultivation; great areas of the country were being tile-drained and rendered for the first time suitable for arable cultivation, other poor sandy land being reclaimed by marling and claying. A sign of the times was the establishment of the Royal Agricultural Society in 1838, and in its earlier volumes, particularly in the writings of Dr. Daubeny on the scientific side, and those of Philip Pusey on the practical side, a good idea may be formed of the point of view of the intelligent farmer of that date. The science of the time had just reached a point which enabled a general theory of the nutrition of both plant and animal to be formed. In the latter part of the eighteenth century the researches of Priestly, followed up by Ingenhousz and Senebier, had settled the fundamental fact that green plants in sunlight decompose the carbonic acid of the atmosphere, setting free the oxygen and retaining the carbon, this being the source of the carbon which makes up the bulk of the dry matter of plants. A little later De Saussure, who published his *Recherches Chimiques sur la Vegetation* in 1804, confirmed the above-mentioned discoveries and gave them a coherent shape. He then proceeded to discuss the mineral or ash constituents of plants, made a series of analyses of the ashes of various plants, and pointed out the importance of these substances in the nutrition of the plant. Davy, whose lectures on Agricultural Chemistry to the Board of Agriculture were published in 1813, though he did not advance the subject much by his own investigations, yet did much service in presenting to the agricultural public the science that was then available. He laid more stress than before on the importance of the ash constituents and the use of manures to supply them, but he appears still to have considered that much of the carbonaceous matter of plants was directly derived from the humus of the soil, and that the assimilation of carbon from the atmosphere was of minor importance.

Boussingault's memorable work began in 1834, and in 1838 he published the result of the inquiries he had been making on his farm into the principles underlying the rotation of crops. He analysed both the manures applied and the crops removed from the land, and thus demonstrated statistically that the source of the enormous quantities of carbon removed annually can only be the carbonic acid of the atmosphere, not the soil nor the manures applied. In 1840 appeared Liebig's famous report to the British Association on 'Organic Chemistry in its application to Agriculture and Physiology.' Here, building upon the foundations laid by De Saussure and by Boussingault

(for in this direction Liebig was not an original investigator), and illuminating these facts by the light of his own recent discoveries in organic chemistry, Liebig drew out a convincing scheme of the nutrition of the plant. Green plants by the aid of sunlight derive their whole substance from carbonic acid, water, and ammonia, present in the atmosphere and produced by decaying matter in the soil, and the simple inorganic salts which are afterwards found in the ash when the plant is burned. From these simple substances the plant elaborates those compounds of carbon and nitrogen, such as starch, sugar, fat, and the proteids, which the animal requires for its food, and thereby reconverts into the original simpler materials. Liebig's brilliant essay excited universal attention and roused the interest of both the scientific and practical men of all civilized countries in the subject, so that to a very large extent we can date modern agricultural science from this stimulating publication. Henceforward we may take it that the source of the carbon of vegetation was no longer regarded as doubtful; it came from the atmosphere, and the humus of the soil practically contributed nothing to it.

The origin of the nitrogen was however by no means so settled. De Saussure had concluded that plants were unable to assimilate the free nitrogen of the atmosphere, but obtained it from the nitrogenous compounds in the soil, and from the small amount of ammonia which he showed to be present in ordinary air. Boussingault took out statistics of the nitrogen as well as the carbon supplied in manures and recovered in the crops. In 1838 he also published an account of experiments in which plants were grown in pots and supplied with known amounts of combined nitrogen, to ascertain if the growing plant did assimilate atmospheric nitrogen. While the crop statistics seemed to show in certain cases a considerable surplus of nitrogen, removed in the crops during a rotation, over that supplied in the manure, his direct experiments, made as accurately as the chemistry of the time would permit, indicated that plants drew only nitrogen from the soil or manure.

The arguments of De Saussure and of Boussingault were adopted by Liebig in his first publication. He considered the source of the nitrogen of vegetation was ammonia derived from the decay of the previous generation of plants or brought down from the atmosphere by the rain. In his later editions Liebig somewhat shifted from this point of view and began to minimize the importance of any supply of combined nitrogen to the plant: provided that the soils were supplied with the mineral constituents removed by the crop, he argued that it would be able to grow luxuriantly and obtain for itself all the nitrogen necessary. It is difficult now to estimate exactly the position held by controversialists of more than half a century ago, but there can be little doubt that Liebig over-estimated the amount of ammonia which could be obtained from the atmosphere, and that he and his followers, arguing from general grounds as to the origin of the original stock of combined nitrogen in the world, were disposed to believe that some, if not all, leafy plants could assimilate and fix free atmospheric nitrogen.

Some little time before the publication of Liebig's report, Lawes had begun his experiments on a small scale. As early as 1835 he was making trials in pots at Rothamsted, and these were year by year extended to the fields on the home farm, until in 1843 the scale had so far increased that he secured the co-operation of Gilbert, and the Rothamsted experiments, as we now know them, began.

Curiously enough, at this very time (1824) Dr. Daubeny, some of whose lectures Lawes had attended at Oxford, was writing in the new *Journal of the Royal Agricultural Society*, about the necessity of systematic experiments to ascertain the value of manures: 'I know not how such experiments can well be instituted except it be on an experimental farm, established for the purpose and placed under scientific hands. Productive of no immediate advantage to the land on which they are tried beyond what could be equally well attained by a much inferior expenditure of labour, they are not likely to be taken up by any private individual who combines practical experience and pecuniary resources with the requisite scientific skill; and even if such a person were to present himself, what guarantee can we offer to the world that he possesses the requisite qualifications?' For it should be remembered that this was the period of the first introduction of what we now call artificial manures. The virtue of bones had long been known, and at Liebig's instigation their phosphoric acid was being made soluble by acid, and dissolved bones were becoming an article of commerce. Lawes had followed up Henslow's discovery of coprolites by converting them into mineral superphosphate, and setting up the earliest manufactory of artificial manures. The first importations of Peruvian guano had been made, and nitrate of soda was also beginning to find its way into the country.

With these and many other substances Lawes had been experimenting on a small scale, and the results of his trials and all his farming experience went to show that a supply of combined nitrogen, in some form or other, was not only necessary to the crop, but on the whole determined its yield to a far greater extent than the supply of ash constituents. Yet Liebig's argument in the second (1843) edition of his report all inclined to represent the mineral manures as fundamental, and a supply of combined nitrogen as unnecessary, or at least of secondary importance. This question of the value or otherwise of nitrogenous manures supplied the main guiding principle in the design of all the earlier field experiments at Rothamsted, as will be evident when the individual fields come to be considered, and the controversy which arose with Liebig on the publication of the first reports from Rothamsted endured for more than a generation. Indeed, the source and fate of the nitrogen of vegetation remained in one form or another the dominant interest in the Rothamsted experiments up to the deaths of Lawes and Gilbert.

The evidence from the field experiments that farm crops require a supply of combined nitrogen will be considered elsewhere, as also the results of the determinations made of the

amounts of ammonia and other nitrogenous compounds brought down by the rain. In neither case was there evidence that a normal vegetation could supply itself with the necessary nitrogen from atmospheric sources only. Attempts had also been made to grow plants in artificial media with a known supply of nitrogen, which could be compared with the amount of nitrogen found later in the fully grown plant. Boussingault, to whom the first experiments of this nature were due, soon found that very elaborate precautions must be taken to obviate the influx of nitrogen either in dust or as ammonia in the atmosphere and in the water employed, hence in all his later experiments the plants were grown in closed cases fed with air from which all ammonia had been withdrawn by acid. Boussingault's conclusions were against the fixation of any nitrogen, but they were not accepted universally. In particular, Ville brought forward other similar experiments, in which the plant showed a distinct gain of combined nitrogen. In 1857 the subject was taken up at Rothamsted, and a most elaborate series of experiments was carried out by Dr. Evan Pugh, at that time working in the Rothamsted laboratory. The experimental plants were grown under glass shades, and every precaution was taken to ensure the freedom from ammonia of the air entering the shades, and also of the other materials—the burnt earth, the pots, the water, the manures—employed in the experiment.

The experiments were made with wheat, barley, oats, clover, beans, peas, and buckwheat, and the trials were repeated, in the one case with no manure in the pots, and in the other with the supply of a small quantity of sulphate of ammonia. The soils employed were made up from either ignited pumice or ignited soil, and the glass shades under which the plants were grown rested in the groove of a stoneware vessel, mercury being used as a lute. The air, previously passed through sulphuric acid and sodium carbonate solution and washed, was forced into the apparatus, so as always to maintain a greater pressure inside than out, thus minimizing all danger of unwashed air leaking in. Carbonic acid was also introduced as required. Under these rigorous conditions the results shown in Table I were obtained.

These results seem to exclude the possibility of any fixation of nitrogen by living plants, and as they had been obtained with plants of three different natural orders, and both without and with manure to induce an initial vigorous growth, for many years the whole trend of scientific opinion was against the possibility of the fixation of nitrogen by living plants.

There remained, however, a number of facts difficult to account for: although laboratory experiments similar to those just described, but resulting in a gain of nitrogen, could be dismissed as vitiated by the many possible sources of error, yet the statistics of the nitrogen collected by various crops could not be explained in any such fashion. It has already been mentioned that Boussingault made out a balance-sheet of nitrogen supplied in manure and removed in crop during

TABLE I.

Summary of the results of experiments made at Rothamsted to determine whether plants assimilate free nitrogen.

			Nitrogen—Gram. In seed and manure if any.	Nitrogen—Gram. In plants, pots, and soil.	Nitrogen—Gram. Gain or loss.	Ratio of nitrogen recovered to nitrogen supplied.
With no combined nitrogen supplied beyond that in the seed sown.						
Gramineae	1857	Wheat ...	0·0080	0·0072	– 0·0008	0·90
		Barley ...	0·0056	0·0072	+ 0·0016	1·29
		" ...	0·0056	0·0082	+ 0·0026	1·46
	1858	Wheat ...	0·0078	0·0081	+ 0·0003	1·04
		Barley ...	0·0057	0·0058	+ 0·0001	1·02
		Oats ...	0·0063	0·0056	– 0·0007	0·89
	1858	Wheat ...	0·0078	0·0078	...	1·00
		Oats ...	0·0064	0·0063	– 0·0001	0·98
Leguminosae	1857	Beans ...	0·0796	0·0791	– 0·0005	0·99
	1858	Beans ...	0·0750	0·0757	+ 0·0007	1·01
		Peas ...	0·0188	0·0167	– 0·0021	0·89
Other plants	1858	Buckwheat	0·0200	0·0182	– 0·0018	0·91
With combined nitrogen supplied.						
Gramineae	1857	Wheat ...	0·0329	0·0383	+ 0·0054	1·16
		" ...	0·0329	0·0331	+ 0·0002	1·01
		Barley ...	0·0326	0·0328	+ 0·0002	1·01
		" ...	0·0268	0·0337	+ 0·0069	1·25
	1858	Wheat ...	0·0548	0·0536	– 0·0012	0·98
		Barley ...	0·0496	0·0464	– 0·0032	0·94
		Oats ...	0·0312	0·0216	– 0·0096	0·69
	1858	Wheat ...	0·0268	0·0274	+ 0·0006	1·02
		Barley ...	0·0257	0·0242	– 0·0015	0·94
		Oats ...	0·0260	0·0198	– 0·0062	0·76
Leguminosae	1858	Peas ...	0·0227	0·0211	– 0·0016	0·93
		Clover ...	0·0712	0·0665	– 0·0047	0·93
	1858	Beans ...	0·0711	0·0655	– 0·0056	0·92
Other plants	1858	Buckwheat	0·0308	0·0292	– 0·0016	0·95

different rotations. He found that while in a rotation of wheat and fallow alone the wheat contained rather less nitrogen than was applied as manure, yet other rotations in which clover was included, and particularly a five-years' continuous cropping with lucerne, gave a large surplus of nitrogen removed over that supplied. Similar evidence was accumulated at Rothamsted and was made more cogent by the analysis of the soils, which showed not only no decrease but an actual gain of nitrogen during the period when the leguminous crop was producing such large quantities of nitrogenous matter above ground. Thus when the various crops were grown continuously with mineral manures * but without any supply of combined nitrogen, the following average amounts of nitrogen per acre were taken away :—

TABLE II.

AVERAGE REMOVAL OF NITROGEN PER ACRE BY CROPS GROWN CONTINUOUSLY WITH MINERAL MANURES ONLY.

		Nitrogen removed per acre.
		lb.
Wheat	24 years	22·1
Barley	24 years	22·4
Root crops ...	30 years	16·4
Beans	24 years, of which 2 fallow	45·5
Clover	22 years, 6 crops only ...	39·8

In a comparison of the alternate wheat and fallow plots with the adjacent plots continually under leguminous plants, the comparative figures shown in Table III were obtained after both had been under a similar treatment for many years.

In another experiment in Little Hoos Field, after five years' cropping by cereals without any nitrogenous manure, in 1872 a portion of the field in barley was sown with clover; in 1873 this portion carried a clover crop which was cut three times, the other portion which had not been sown with clover was again cropped with barley. Determinations of the nitrogen removed in 1873 showed 151 lb. in the clover crop, and 37 lb. per acre in the barley crop, respectively. In the following year (1874), barley was again sown over the whole area, but the barley crop which followed clover took away nearly twice as much nitrogen

* The term mineral manures will be used throughout for mixtures of the constituents found in the ash of plants, i.e., phosphates, sulphates and chlorides of sodium, potassium, calcium, and magnesium, but always excluding nitrogen in any form.

as that which followed barley, although this had contained less than the corresponding clover. Yet an analysis of the soil immediately after the 1873 crop had been removed showed more nitrogen in the land where clover had been growing than where the barley had been growing, as shown in Table IV, where all the results are summarized.

TABLE III.

NITROGEN IN CROP AND SOIL. LEGUMINOUS PLANTS COMPARED WITH WHEAT AND FALLOW. HOOS FIELD.

	Unmanured.	Mineral manures only, 30 years.		
	Wheat and fallow alternately.	Trifolium repens.	Melilotus leucantha.	Medicago sativa.
	lb.	lb.	lb.	lb.
Average annual removal of nitrogen, 8 years (1878-85)	12	33	71	110
Nitrogen per cent. in surface soil in 1885... ...	0·1021	0·1269	0·1151	0·1219
Nitrogen as nitric acid in soil and subsoil to the depth of 9 feet, per acre, 1885	42	101	79	17

TABLE IV.

NITROGEN ACCUMULATED BY CLOVER CROP. LITTLE HOOS FIELD.

Year, etc.	Pounds of nitrogen per acre in crop removed.	
	Plot A.	Plot B.
1873	Barley, 37·3	Clover, 151·3
1874	Barley, 39·1	Barley, 69·4
Nitrogen per cent. in soil at end of 1873	0·1416	0·1566

In yet another experiment, land which had previously grown beans and then been fallow for five years was sown with barley and clover in 1883, the clover being allowed to stand in 1884 and 1885. At starting, the soil was analysed. The surface 9 inches contained on an average 2,657 ℔. per acre of nitrogen, while of nitrogen as nitric acid the soil only contained 25·7 ℔. per acre down to a depth of 6 feet. As a result of the three years' cropping with barley and clover, and then with clover only, an average amount of 319·5 ℔. of nitrogen was removed. Yet the soil contained, on analysis at the end of the experiment, 2,832 ℔. of nitrogen per acre in the top 9 inches, or a gain of 175 ℔. per acre in the three years; making a total, with the crop removed, of nearly 500 ℔. of nitrogen per acre to be accounted for.

Experiments like these, coupled with the long experience of practical farmers of the beneficial effects of the growth of clover and other leguminous plants on the succeeding crops in a rotation, led many men to think that there still might be fixation of nitrogen by leguminous plants in spite of the apparent exclusion of any such hypothesis by Pugh's experiments at Rothamsted. Voelcker, in England, when discussing the power of a clover crop to accumulate nitrogen, expressed the opinion that the atmosphere furnishes nitrogenous food to that plant; in France it was maintained by Ville. Berthelot also brought evidence to show that the soil itself, by the aid of microscopic vegetation, assimilated some free nitrogen.

Lawes and Gilbert themselves were disposed to look to the subsoil as the source of this excessive amount of nitrogen, and were conducting experiments to ascertain whether the widely ranging roots of the leguminous plants, in virtue of their highly acid sap, did not possess some special power of attacking the dormant nitrogenous compounds in the subsoil, when the clearing up of the whole subject came with the publication, in 1886, of the researches of Hellriegel and Wilfarth. These investigators found that when plants were grown in sand and were fed with nutrient solutions, the Gramineae, the Cruciferae, the Chenopodiaceae, the Polygoneae, grew almost proportionally to the amount of combined nitrogen supplied; and if this were absent, nitrogen starvation set in as soon as the nitrogen of the seed was exhausted. With the Leguminosae, however, a plant was observed sometimes to recover from the stage of nitrogen starvation and begin a luxurious growth which lasted until maturity, though no combined nitrogen was supplied. In such cases the root of the plant was always found to be set with the little nodules characteristic of the roots of leguminous plants when growing under natural conditions. Further experiments were made in which the plants were grown in sterile sand, but as soon as the stage of nitrogen hunger was reached, a small portion of a watery extract of ordinary cultivated soil was added; whereupon the plants receiving the extract recovered from their nitrogen starvation and grew to maturity, assimilating considerable quantities of nitrogen. The renewed growth and the assimilation of nitrogen were always found to be attendant upon the production of nodules on the roots. The nodules

were found to be full of bacteria, to which the name of *Bacillus radicicola* has been given. They could only be produced by previous infection, either by an extract of the crushed nodules or of a cultivated soil, in some cases (lupins, serradella) only by soil which had previously carried the same crop.

Gilbert had been present at the meeting of the Naturforscher Versammlung at Halle when Hellriegel and Wilfarth read their paper, and on his return to England experiments were immediately begun at Rothamsted to check their results.

A series of small pits was built up of slate slabs out of doors, and these were filled with either soil or washed sand and then sown with various leguminous plants, which were afterwards inoculated or not as desired. The growth was cut away for the determination of dry matter produced, and the nitrogen collected; afterwards the roots were washed out from the soil or sand for the examination of the development of the nodules.

A more rigorous set of experiments was carried out in glazed stoneware pots in the glasshouse, and some of the results obtained are set out in Table V.

The table consists of a balance-sheet for the nitrogen only, in which the nitrogen supplied, either in the seed, in the sand or soil used, in the extract employed for inoculation, or in a few cases in the manure, is compared with that recovered in the soil or the plant. The first horizontal line for each plant shows the results obtained when there was no inoculation and the plant grew with simply the store of nitrogen present in the seed and what it could obtain from the soil; the second and third lines show the results of inoculation, both seed and soil being otherwise similar; the fourth line shows the result when the seeds were sown in ordinary soil.

It is needless to elaborate the results thus obtained: they confirmed, as has repeatedly been done since, the conclusions of Hellriegel and Wilfarth, and showed that the leguminous plants possess the power of 'fixing' nitrogen under ordinary conditions of field culture by the agency of the bacteria living in the nodules on their roots.

The very rigour with which the earlier laboratory experiments, like those at Rothamsted on peas and beans in 1857-8, had been carried out, had prevented any fixation of nitrogen by excluding all possibility of inoculation.

The interpretation of the increased stock of nitrogen obtained with leguminous crops, which, as instanced above, had hitherto been so difficult of explanation, at once became apparent, and the long controversy as to the sources of nitrogen in vegetation was thus closed by a vindication of both schools of opinion.

Lawes and Gilbert were perfectly correct in maintaining that the ordinary green plant has no power of fixing nitrogen, but the whole class of leguminous plants form an exception when grown under ordinary field conditions, for then they become collectors of atmospheric nitrogen in virtue of the nodule bacteria with which they are associated.

TABLE V.

Plant.	Pot number.	Duration of experiment.	Nitrogen. At beginning. In soil, soil-extract, and seeds.	Nitrogen. At beginning. Total.	Nitrogen. At end. In sand or soil.	Nitrogen. At end. In produce.	Nitrogen. At end. Total.	Gain or loss of nitrogen.	Ratio of nitrogen of infected plants to uninfected.
Annuals.									
		Weeks.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	
Peas	1	15	0·0265	0·0265	0·0090	0·0125	0·0215	−0·0050	...
	2	15	0·0273	0·0273	0·0108	0·1475	0·1583	+0·1310	11·8
	3	15	0·0270	0·0270	0·0162	0·1825	0·1987	+0·1717	14·6
	4	15	6·9422	6·9422	6·8817	0·2075	7·0892	+0·1470	...
Vetches ...	9	15	0·0137	0·0137	0·0184	0·0065	0·0249	+0·0112	...
	10	15	0·0141	0·0141	0·0260	0·1651	0·1911	+0·1770	25·4
	11	15	0·0139	0·0139	0·0230	0·1868	0·2098	+0·1959	28·7
	12	15	7·5966	7·5966	7·3052	0·2087	7·5139	−0·0827	...
Yellow Lupins	17	21	0·0375	0·0375	0·0551	0·0153	0·0704	+0·0329	...
	18	21	0·0378	0·0378	0·0523	0·4980	0·5503	+0·5125	32·5
	19	21	0·0380	0·0380	0·0594	0·4914	0·5508	+0·5128	32·1
	20	21	6·0408	6·0408	6·7883	0·2146	7·0029	+0·9621	...

TABLE V.—(*Concluded.*)

Plant.	Pot number.	Duration of experiment.	Nitrogen. At beginning. In soil, soil-extract, and seeds.	Nitrogen. At beginning. Total.	Nitrogen. At end. In sand or soil.	Nitrogen. At end. In produce.	Nitrogen. At end. Total.	Gain or loss of nitrogen.	Ratio of nitrogen of infected plants to uninfected.
Plants of longer life.									
		Weeks.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	
Red Clover ...	5	77	0·0082	0·0082	0·0273	0·2094	0·2367‡	+0·2285	...
	6	77	0·0089	0·0089	0·0312	0·2885	0·3197	+0·3108	...
	7	77	0·0083	0·2381*	0·0323	0·2986	0·3309†	+0·0930	...
	8	77	6·4274	6·4274	6·3198	1·7288	8·0486	+1·6212	...
Lucerne ...	21	68	0·0231	0·0231	0·0200	0·0030	0·0230	−0·0001	...
	22	75	0·0247	0·0247	0·0514	0·3589	0·4103	+0·3856	119·6
	23	76	0·0236	0·3278*	0·0371	0·4307	0·4917†	+0·1639	143·5
	24	76	17·4983	17·4983	16·8141	1·2345	18·0486	+0·5503	...
White Clover	33	131	0·0110	0·0110	0·0148	0·0016	0·0164	+0·0054	...
	34	131	0·0119	0·0119	0·0575	0·7098	0·7673	+0·7554	443·6
	35	131	0·0120	0·0120	0·0482	0·5465	0·5947	+0·5827	341·6
	36	131	...	...	5·3423	3·4726	8·8149	...	...
	37	131	0·0081	0·6746*	0·0459	0·4430	0·6754†	+0·0008	...

* Including calcium nitrate, added as follows:—Pot 7, 0·2298 gram.; Pot 23, 0·3042 gram.; and Pot 37, 0·6665 gram.
† Including also the following amounts of nitrate recovered:—Pot 7, none; Pot 23, 0·0239 gram.; and Pot 37, 0·1865 gram.
‡ Accidentally inoculated.

Without doubt, Hellriegel and Wilfarth's discovery came as somewhat of a disappointment to the Rothamsted investigators. Although the statistics they had accumulated form to this day the best demonstration of its truth on a field scale, still they had so long and so rightly upheld the necessity of combined nitrogen to the nutrition of the plant, that to have to concede the point in issue, as far even as the leguminous plants were concerned, could not have been welcome. Indeed, Liebig's idea having thus triumphed in the one special case, his most sweeping generalization was justified—that it is the function of plants to manufacture the complex nitrogen compounds from elementary nitrogen, just as they do the carbon compounds from the carbon dioxide in the atmosphere. These complex nitrogen and carbon compounds are necessary to animals, which derive their vital heat and energy by breaking them down again into the simpler materials used by the plant. In this eternal cycle Liebig had placed nitrogen alongside of carbon, and though the statement may be true only of the particular leguminous plants, it is true in a general sense, in that these plants (or rather the bacteria with which they are associated) are probably the original sources of the world's stock of combined nitrogen.

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IMPERIAL DEPARTMENT OF AGRICULTURE FOR THE WEST INDIES.

The following review of the efforts of the Imperial Department of Agriculture for the West Indies is contained in a letter addressed by Sir Daniel Morris, K.C.M.G., D.Sc., etc., to the Secretary of State for the Colonies, forwarding a report on the Department, which has been published as Colonial Reports—Miscellaneous, No. 36 :—

Barbados,
January 31, 1906.

Sir,

I have the honour to submit a report on the working of the Imperial Department of Agriculture in the West Indies.

The Department was created in 1898, on the recommendation of the West India Royal Commission. This Commission consisted of Sir Henry Norman, G.C.B., G.C.M.G., C.I.E., Sir Edward Grey, Bart., and Sir David Barbour, K.C.S.I., K.C.M.G.

It was charged to inquire into the condition and prospects of the sugar-growing colonies in the West Indies, and to suggest such measures as would appear best calculated to restore and maintain the prosperity of those colonies and their inhabitants.

A further subject of inquiry was whether, in the event of the production of sugar being discontinued or considerably diminished, other industries, and what, could replace it and be carried on profitably and supply employment for the labouring population.

In their report, presented in August 1897, the Commissioners stated that, 'In most of the West Indies the products of the sugar-cane, though they are now valued at prices which are much below those which prevailed a few years ago, still form the larger portion of the total exports of native produce.

'The gravity of the immediate danger to the welfare of each colony, which would arise from a failure of the sugar-cane industry, may, for practical purposes, be measured by the proportion which the exports of sugar, rum, and molasses bear to the total exports of that colony. In such an event,

the welfare of each colony would, in the long run, however, depend on the extent to which it might be found possible to establish other industries.'

The funds for the maintenance of the Department have been provided since 1898 by a yearly grant by Parliament. The average amount expended has been at the rate of £17,400 per annum, allotted approximately as follows: Salaries and incidental expenses (Head Office), £5,000: grants-in-aid, £12,400.

In Barbados and in the Windward Islands (Grenada, St. Lucia, and St. Vincent) and the Leeward Islands (Dominica, Montserrat, Antigua, St. Kitt's, Nevis, Anguilla, and the Virgin Islands) the grants-in-aid have been expended in the maintenance of botanic and experiment stations and agricultural education; in Jamaica, in providing the services of an agricultural lecturer; in British Guiana, in assisting experiments in improving the sugar industry; and in Trinidad (for Tobago), in maintaining a botanic and experiment station.*

The Imperial Commissioner is directly in charge of the administration of the agricultural grants at Barbados and in the Windward and Leeward Islands, and is consulting officer in agricultural matters to the Governments of Jamaica, British Guiana, and Trinidad.

The duties entrusted to the Department were the general improvement of the sugar industry and the encouragement of a system of subsidiary industries in localities where sugar cannot be grown, or where the conditions are more favourable for the production of cacao, coffee, bananas, limes, cotton, rubber, cocoa-nuts, sisal hemp, rice, nutmegs, pine-apples, and other crops.

In addition, it was proposed that it should devote attention to the improvement of the breed and condition of cattle, horses, and small stock, and to the extension of bee keeping for the production of honey and bees'-wax.†

As it was realized that substantial progress was impossible until the mass of the people (wholly dependent on the products of the soil) were brought into sympathy with agriculture and trained to regard the successful treatment of crops as the basis upon which to build, not only their own welfare, but the general prosperity of these colonies, a prominent position has been given to teaching the principles of elementary science and agriculture, both in the primary and secondary schools.

Associated with this policy was the increased attention devoted to object-lessons, the encouragement of growing specimen plants in pots and boxes, and the establishment of school gardens. Arbor days for the public planting of ornamental and other trees have also been organized and assisted by the Department.

The details of the working of the Department have been regularly presented and discussed at the several West Indian

* The grants-in-aid of Jamaica, British Guiana, and Trinidad (for Tobago) were withdrawn on March 31, 1906.

† The annual value of the bee-keeping industry in Jamaica is about £17,000.

Agricultural Conferences, at which the officers of the Department and the representatives of the Agricultural and Commercial Societies and of the several educational bodies in the West Indies have taken an active part. The proceedings of these Conferences have been published in full in the *West Indian Bulletin* and the *Agricultural News*.

Sugar Industry.

In British Guiana, Barbados, Antigua, St. Kitt's, and Nevis sugar is the staple industry, and upon its success depends the welfare of the inhabitants and the resources of the Governments. In Trinidad and Jamaica sugar, it is true, occupies a secondary position, but it would seriously affect both these colonies if the industry were further reduced or abandoned. Other islands in which sugar is grown to a greater or less extent are Tobago, St. Vincent, and Montserrat. In Grenada and Dominica practically little or no sugar is produced.

The Imperial Department of Agriculture has devoted special attention to the scientific investigation of questions affecting the sugar industry. The average expenditure in this direction in Barbados, Antigua, St. Kitt's, and British Guiana has been at the rate of nearly £4,000 per annum. The investigations have been mainly directed to raising new seedling varieties of sugar-canes, capable of withstanding diseases that rendered the continued cultivation of the Bourbon and allied canes impossible, and raising standard varieties capable of producing a larger yield of sugar per acre. Valuable experiments have also been carried on, over considerable areas, in testing the relative value of pen and artificial manures, and in ascertaining, by a continuous series of trials under skilled supervision, in what quantities and at what stages of growth of the canes such manures can be applied to the best advantage. In addition, investigations have been carried on in the chemical selection of the sugar-cane, in the treatment with germicides of cane tops, and as to the effect of planting at different distances and tillage operations.

In all these directions the results already to hand are of a striking character. The following is a brief summary, in continuation of the valuable information presented by the several officers directly in charge of experiments at the Agricultural Conference held at Trinidad in January 1904* :—

BRITISH GUIANA.

The total area under cultivation in sugar-cane in British Guiana is 78,003 acres, including 2,500 acres cultivated by small farmers. This is an increase of 11,095 acres as compared with 1896. The average cost of producing 1 ton of first centrifugal sugar, including 14 per cent. second sugar and 25 gallons of rum, was £10 9*s*. 2*d*. in 1903, as compared with £11 9*s*. 2*d*. in 1896. In 1897 only small areas of land were occupied with canes of other varieties than Bourbon, while at the present time

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* See *West Indian Bulletin*, Vol. V, pp. 335-90, and Vol. VI, pp. 1-60.-[Ed. *W.I.B.*]

about 14,000 acres are planted with them.* The results of experiments on a large scale with seedling and other canes than Bourbon recorded during the last three years 'indicate an increased yield per acre of from 12 to 20 per cent. over that of the Bourbon.' The Sugar-cane Committee of the Board of Agriculture states that this increase has been obtained by the substitution of certain new varieties for the Bourbon cane 'without increase in the cost of cultivation and possibly with a lessened outlay for manure.' It is added that 'in many of the experiments the varieties, other than the Bourbon, have been cultivated on land on which the latter cane does not flourish, while the Bourbon returns are, as a rule, from land of average fertility, upon which it gives satisfactory returns.'

The following are the principal varieties of canes other than Bourbon cultivated in British Guiana:—D. 109 (3,338 acres), White Transparent (2,876 acres), B. 147 (1,138 acres), D. 625 (537 acres), and B. 208 (417 acres).†

As confirming what is stated by the Sugar-cane Committee, and as showing what has been done with seedling canes on a large scale at the Diamond estate, in British Guiana, the manager states, as the result of experiments carried on for four years (1901-4 inclusive), that seedling canes grown on an average area of 1,537·918 acres, as compared with Bourbon canes grown on an average area of 2,824·352 acres, have proved better than the Bourbon to the average extent of 24 per cent.** The average crop reaped during the period under review was 10,560 tons of sugar.

Further information in regard to the sugar industry in British Guiana and the interesting results obtained in that colony under the direction of Professor J. B. Harrison, C.M.G., is contained in the *West Indian Bulletin*, Vol. V, pp. 335-57.

BARBADOS.

In Barbados, during the last five years, 20,407 varieties of seedling canes have been raised. Less than 1 per cent. of these have stood the stringent tests of field and chemical selection applied to them. The seedling experiments in hand up to December 31, 1903, consisted of 8,120 plots, covering 143·294 acres. Experiments with manures consisted of 106 plots, covering an area of 14·196 acres, while another set of manurial experiments consisted of eighteen plots, covering an area of

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* In a report issued by the British Guiana Board of Agriculture on June 5, 1906, it is stated that 21,481 acres are now occupied with varieties other than Bourbon—an increase of 45·7 per cent. on the acreage in 1905-6.—[Ed. *W.I.B.*]

† The same report gives the acreage occupied by the principal varieties other than Bourbon for the crop 1906-7 as follows: D. 109 (8,386 acres), D. 625 (3,357 acres), B. 208 (2,125 acres), D. 145 (1,842 acres), B. 147 (1,733 acres), and White Transparent (1,416 acres).—[Ed. *W.I.B.*]

**More recent returns, published in the *Agricultural News* (Vol. V, p. 99), show that 'the average superiority of seedling canes over the Bourbon cane on plantation Diamond, over a period of five years, is at the rate of 25·6 per cent.'—[Ed. *W.I.B.*]

16·02 acres. The general results are favourable, and indicate that the efforts that are being made are in the right direction and justify the opinion that the raising of seedling canes affords special promise, as in British Guiana, of increasing the yield, and diminishing the cost of cane sugar production in this island.

About 35,000 acres of canes are reaped annually in Barbados. According to a return prepared by Mr. Bovell in 1903, the Bourbon cane, owing to the prevalence of disease, has been almost entirely discarded of late years. The area under cultivation in this cane in 1903 was 328 acres. The area under other canes in 1903 was approximately as follows: White Transparent, 18,566 acres; Rappoe, 3,089 acres; Caledonian Queen, 1,661 acres; B. 147, 1,642 acres; B. 208, 342 acres. The area under seedling canes is gradually extending. The figures for 1904 are not yet available. Of the newer canes, the most promising is B. 1,529. The cultivation of this cane (on account of the large yield per acre and the purity of its juice) is being extended to as many experiment plots as possible during the present planting season.*

In presenting the report on the experiments carried on at Barbados during the crop seasons 1903-5, Messrs. d'Albuquerque and Bovell called attention to new seedling canes, still under trial, such as B. 1,753, which had given saccharose at the rate of 11,516 ℔. per acre; B. 3,289, at the rate of 10,705 ℔. per acre; B. 1,030, at the rate of 10,485 ℔. per acre; B. 1,355, at the rate of 10,302 ℔. per acre; B. 6,048, at the rate of 10,102 ℔. per acre; B. 3,696, at the rate of 9,828 ℔. per acre; while the White Transparent (the cane now generally cultivated in the island) for the same two years had given 6,452 ℔. of saccharose per acre only. The glucose per gallon of the new canes was also satisfactory.

Referring to B. 147, it was stated that, on one estate during the crop season 1903-5, this cane, as a plant cane, had given 320 ℔. per acre of merchantable sugar more than the White Transparent. On the same estate there had been reaped as ratoons during the two years an average of 44 acres of B. 147, and this cane had given 599 ℔. more saccharose per acre than the White Transparent.

In regard to the manurial experiments at Barbados, the results confirmed those obtained in previous years. They indicated that an ordinary application of farmyard manure, together with artificial manure, was more effective than a very large application of farmyard manure without artificial manure; also that the application of nitrogen, both to plant canes and to ratoons, was followed by a profitable increase in the yield. The application of sulphate of potash was generally profitable. On the other hand, phosphatic fertilizers either had no effect upon the yield or caused a diminution.

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* See *West Indian Bulletin*, Vol. V, pp. 357-66.—[Ed. *W. I. B.*]

LEEWARD ISLANDS.

In the Leeward Islands Dr. Francis Watts has recently presented the results obtained during the last five years in regard to the introduction of seedling canes and manurial experiments at Antigua and St. Kitt's.

In Antigua there are about 8,000 acres under cane cultivation. The principal varieties are the White Transparent (under which is included Naga B., Mont Blanc, and Caledonian Queen), B. 147, D. 95, and B. 208. The area under Bourbon is reduced to about 204 acres. By means of the introduction of new varieties of canes, Dr. Watts states, 'the planter has now an opportunity of selecting his canes for particular soils and situations or for early or late planting. In this way he may not necessarily select that cane which has done best on the average of the whole of the experiments, but his own observation may have led him to see that some particular cane will prove suitable for some special conditions, and he selects suitable canes accordingly.'

At St. Kitt's the total area under canes is estimated at 7,000 acres. The principal canes cultivated are what are known as the 'Jamaica', Caledonian Queen, and White Transparent. The area under seedling cane B. 147 is about 1,700 acres, and under B. 208, 130 acres. The area under Bourbon is about 340 acres.

At one time cane diseases in this island 'invaded one area after another until fears were entertained that some estates must be abandoned, and sugar-growing cease upon them. Following the advice of the Department of Agriculture, those planters, whose canes were being destroyed by the ravages of disease, introduced other varieties, notably B. 147, with the happiest results; plantations which were in danger of abandonment are now bearing luxuriant crops, to the great relief and satisfaction of their owners.'

In summing up, Dr. Watts states: 'It will be seen that the newly-introduced varieties of canes, including some of the newly-discovered seedlings, have already played an important part in the sugar industry of the Leeward Islands. The work of their introduction is highly regarded by planters who freely express their appreciation of the advantages they have derived, and the feeling is now engendered that in the selection of varieties of cane they are in possession of a powerful defence against many forms of cane diseases.'*

In a report on the condition of the sugar industry in Antigua and St. Kitt's during the period 1881-1905 (dated November 29, 1905), † Dr. Watts states:—

'The stability given to the sugar industry by the abolition of bounties by the operation of the Brussels Convention has already led to a considerable amount of development in the

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* See also *West Indian Bulletin*, Vol. V, pp. 366-82.—[Ed. *W.I.B.*]

† Published in the *West Indian Bulletin*, Vol. VI, pp. 373-86.—[Ed. *W.I.B.*]

sugar industry in Antigua in the past two years. The erection and successful operation of the Central Sugar Factory at Gunthorpe's, at a cost of £45,358, the conversion of Bendal's sugar factory into a small but well-equipped modern factory at a cost of some £12,000, together with the extensive substitution of railway and tramway haulage for less perfect methods at both these factories, indicate a desire for progress such as has not been seen in the smaller islands for a generation or more, and is good evidence of a determination to do the best to make the industry successful.

'Nor does the tendency towards progress end here. Two sets of steam-ploughing plant are expected to arrive in Antigua within the next few weeks, one set being imported for working the lands associated with each of the above-mentioned factories; these, by deeper cultivation of the soil, are calculated to minimize the effects of drought. Concurrently with this, we may expect other improvements, all of which must have their effect on the production of sugar and upon the welfare of the island.

'We are therefore justified, I think, in making some forecast of the future, and may reasonably hope to see the sugar crop in Antigua, not only reaching to, but, by virtue of the improvements now introduced, exceeding, the crops of the period 1881-94; that is, exceeding, on the average, 13,000 tons. The price of sugar will doubtless be low, but at £8 per ton, at which price in an average year sugar can be produced at a small profit, this is worth £104,000, while doubtless there will be a steady increase in the amount of crystal (vacuum pan) sugar produced and a diminution of muscovado, thus increasing the value of the output. In addition to this, we may look forward to those developments which are sure to arise when the planting body is stimulated to a degree of activity exceeding anything which has existed in the past. Increased areas and improved methods of cultivation, improved varieties of canes, and various other improvements, such as may be anticipated from the intelligent working of a well-equipped Department of Agriculture and active and alert planters, cannot fail to result in beneficial changes.'

TRINIDAD.

In Trinidad the Otaheite or Bourbon cane is generally cultivated. Owing to the absence of serious disease and to the generally good results obtained from the present canes, systematic experiments on a large estate scale with seedlings and manures have apparently not been regarded as a necessity, as in the other colonies. Seedlings raised locally, or obtained from elsewhere, have been grown on a small scale at the St. Clair Experiment Station, and the canes analysed by the Government Chemist. The results have been published in the *Proceedings* of the Agricultural Society and the Annual Reports issued by the Botanical Department.

As a result of an experiment with a seedling cane (D. 95), as compared with the Bourbon and White Transparent canes, carried on by the Trinidad Estates Company under the

direction of Dr. A. Urich,* the following figures may be of interest :—

Recapitulation (Tons of Cane per Acre).

——	Plants.	1st. Ratoons.	2nd. Ratoons.	Average, actual.	Acres cut.
Bourbon ...	21·05	16·42	15·34	16·43	604
White Transt.	27·53	19·88	15·15	22·35	935
D. 95	32·85	20·68	20·88	23·65	225

At Caroni estate, Trinidad, what is known as the Naudet patent process of extracting and purifying cane juice was on trial during the season 1904-5. The results were short of expectations, owing to the defects in the first milling, the cane not being opened up sufficiently to give good diffusion results. It is, however, claimed that there was a gain over double milling. At Porto Rico the results were more favourable: 'The extraction was 96 per cent. of the total juice in the cane, with a dilution of 9 per cent. on the weight of the cane, and the density of the juice from the diffusion battery was only 0·7° Beaumé less than the juice from the mill. This juice was also of equal purity to the juice from the mill.'

JAMAICA.

A law was passed by the Legislature of Jamaica in August 1903, by which the Imperial grant-in-aid of the sugar industry (£10,000) was appropriated for the maintenance, under the direction of Mr. Cousins, of experimental stations, with special reference to the chemistry and mycology of sugar and rum. A Fermentation Chemist has been appointed in connexion with the rum investigations. The grant is estimated to provide for research and experiment work for six years.

In regard to seedling canes, Mr. Cousins states that the best of the seedlings from Demerara and Barbados have been carefully tested in Jamaica. Two of these stand out in a prominent manner. 'Barbados seedling No. 208 appears to be well suited to all parts of Jamaica, and is probably the best cane now available. At the Hope Experiment Station in 1905 a crop of this variety was harvested, yielding over 70 tons of cane, capable of yielding 7 tons of sugar per acre. Upon light soils in seasonable or irrigable districts, Demerara seedling No. 95 has proved a great success. This cane has given double the yield of crystallized sugar per acre, as compared with the Jamaica cane, and upon a commercial scale under these conditions.'

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* See *West Indian Bulletin*, Vol. V, pp. 382-7.—[Ed. *W.I.B.*]

Further, 'there are districts in the island where the seedling canes already at our disposal are capable of giving a return of at least 30 per cent. more sugar per acre than the Jamaica cane. The seasonable and irrigable areas should benefit with certainty from carefully controlled trials of the most promising seedling canes now in cultivation. Estate trials of ten varieties, specially selected for local conditions, have been arranged on twelve estates.'

As to experiments in manuring canes, Mr. Cousins states:—'Results already obtained show that considerable agricultural returns can be obtained in the cultivation of canes by the use of lime or marl on soils not deficient in humus and nitrogen, by the judicious use of fertilizers where the water supply enables large crops to be grown with some certainty, and, lastly, of the great effect of drainage upon stiff, flat areas of land. It is proposed to extend these experiments, to carry them out with stricter oversight and control, and to aim at the financial demonstration of the results of the operations under test.'

Proposals are in hand for establishing two central sugar factories in the district of Vere, and another in the neighbourhood of Montego Bay. There is also a prospect of improving the rum industry in Jamaica, based on recent investigations carried on by Mr. Cousins.

PEDIGREE SUGAR-CANES.

An important step in advance was made by the Department in 1902 in the hybridization of the sugar-cane, and in raising new seedling varieties by artificial cross-pollination. The details are given in the *West Indian Bulletin* (Vol. VI, pp. 394-402) and in an article under the heading 'Raising Pedigree Sugar-canes' in the *Agricultural News* (Vol. V, pp. 17-8). Some of the new pedigree canes thus obtained are now under cultivation. If, as anticipated, the results of the new method of breeding sugar-canes above referred to are still further extended during the next few years, the prospects of the sugar industry in these colonies should be still further improved. There are now no good reasons why we should not be in a position to produce pedigree sugar-canes as well as pedigree wheat and oats. The work carried on by the Department in raising new seedling canes is closely followed in all sugar-producing countries. According to the Director of Sugar-cane Experiments at Hawaii, the Demerara seedling No. 117 yields from 1 ton to $1\frac{1}{2}$ tons more sugar to the acre than any other variety under trial. In Louisiana the best canes in experiments carried on by Dr. Stubbs were seedling canes D. 95 and D. 74. The Barbados cane B. 147 has given excellent results in Queensland, while another Barbados cane (B. 208) is reported to have given 69 tons of canes per acre, with 22·2 per cent. of sucrose.

In Jamaica, according to Mr. Cousins, the same cane under irrigation gave 66·5 tons of canes per acre.

It may be added, as an instance of what takes place in one island, that over 20,000 plants (tops and portions of stems) of

new seedling canes are annually exported from Barbados to other parts of the West Indies. The area under seedling canes is steadily extending, and it is hoped that a general improvement of the sugar industry will thus result from the conjoined efforts of the Department and members of the planting community.

In concluding this summary of the efforts that have been made to improve the condition of the sugar industry in the West Indies, I desire to place on record my deep appreciation of the valuable assistance that has been afforded to the Department by the proprietors, attorneys, and managers of estates.

It was laid down as an essential feature of the experiments with sugar-cane that the canes should be cultivated on the experiment stations in exactly the same manner as the ordinary crop on the estate, so as to institute a close comparison on the most practical basis between the new seedling canes and those ordinarily grown.

In Barbados, Antigua, St. Kitt's, and Nevis about 200 acres of cane land have been placed at the disposal of the Department for the purpose of experiments, and all expenses of cultivation, and, in some cases, of manures also, have been borne by the estates. A similar co-operation between the officers in charge of experiments and the planters has also obtained in Jamaica and British Guiana.

Whilst steady progress is being made in raising new canes and in the selection and use of manures, the methods that have been adopted for extracting the juice and manufacturing the sugar, except in a few instances, at Jamaica, Barbados, Antigua, Montserrat, St. Kitt's, and Nevis are still far from satisfactory.

Up to 1903, owing to the existence of the continental bounties, the sugar industry in the West Indies had lost its credit, and since the bounties were abolished, sufficient time has not elapsed to enable capitalists to estimate what the effects are likely to be. It is evident, however, that the work of raising new canes, capable of withstanding disease and of yielding an increased amount of sugar, does not cover the whole ground, as until improved machinery for extracting the juice and manufacturing the sugar is in general use in the islands named, it will be impossible for them to compete successfully with other sugar-producing areas.

In the evidence placed before the West India Royal Commission at Barbados, it was stated that there was 'an average loss of over 2,000 ℔. of sugar per acre left in the canes after crushing, which was burnt in the megass'; and again 'for every 100 ℔. of crystallizable sugar contained in the juice, not more than an average of 75 ℔. of ordinary muscovado sugar was recovered.'

At present it takes about 13½ tons of canes to produce a ton of muscovado sugar of the value of £8; while in a well-equipped factory it would only take about 9½ tons of canes to produce a ton of grey crystals, of the value of about £10 10s.

It is also to be borne in mind that muscovado sugar is only in limited demand in the United States and Canada, while grey crystals are readily sold in any quantity.

The establishment of a central factory in Antigua and the publication of the results of working during the first year (1905) have already produced a favourable impression in favour of central factories. The opinion is becoming general that the sugar industry cannot be maintained under existing conditions and that the only possible means of improving it is by the establishment of central factories.

The Royal Commission recommended that, in the case of Barbados, money should be lent by the Home Government for the purpose of establishing central factories, and that 'if the scheme succeeded, it might be extended in Barbados and possibly in the other islands.'

The circumstances in most of the other islands referred to are very similar to those in Barbados. The Hon. F. J. Clarke, President of the Barbados Agricultural Society, in a paper read before the West Indian Agricultural Conference in 1900, expressed his opinion as follows: 'Not only must we have central factories in order to avoid the enormous loss attending the present system of manufacture by means of small and imperfect crushing machinery and open tayches, but to be able to manufacture any class of sugar that may be in demand in the markets of the world.' Further, he stated: 'It is absolutely essential to our existence that central factories should be erected here.' Professor Harrison, with his long experience of Barbados and his more recent acquaintance with the working of central factories in British Guiana, at the same Conference stated: 'There is not the slightest doubt in my mind that, if this colony of Barbados is to continue to exist as a sugar-producing colony, it must adopt the principle of central factories.' And further: 'All I can say is, that I believe the erection of central factories in Barbados would be a means of raising the colony out of its present difficult position and, in fact, prove its salvation.'

Exactly similar remarks apply to Jamaica, St. Vincent, Antigua, Montserrat, St. Kitt's, and Nevis, in all of which the sugar industry might be greatly extended and improved.

Cacao Industry.

A review of the Cacao Industry in the West Indies was published in the *West Indian Bulletin* (Vol. V, pp. 172-7). It would appear that the total exports of cacao from these colonies have risen from 335,817 cwt. in 1898 to 491,873 cwt. in 1902.* These figures indicate that cacao plantations are being very considerably extended throughout the West Indies. The exports of cacao from Trinidad are of the annual value of £1,000,000. Those of Grenada are of the annual value of £250,000. Jamaica comes next with exports of the annual

* In the year 1904-5 the total exports of cacao from the West Indies had risen to about 520,000 cwt.—[Ed. *W.I.B.*]

value of £80,000. It is estimated that about 80,000 plants, besides large quantities of pods, are being distributed from the Botanic Gardens and Experiment Stations every year. The diseases affecting cacao continue to receive careful attention, and planters are kept fully informed as to their character and treatment. So far, the 'Witch Broom' disease, that has so seriously crippled cacao estates in Surinam, has not reached the West Indies.

Experiments in manuring cacao plantations and in dealing with the various diseases affecting cacao trees have been carried on in Trinidad, Grenada, St. Lucia, and Dominica. Mr. Hart reports that recommendations for burying diseased pods are being adopted in Trinidad, with the result that, in one instance, 'a proprietor expected to obtain 25 per cent. more cacao than he otherwise would have done.' Mr. J. G. deGannes, an authority on cacao cultivation, reports that cacao planters in Trinidad are realizing the necessity for higher cultivation, and manuring, where tried, has proved successful. 'Basic slag is the manure more generally applied. Some very good results are obtained by the use of pen manure prepared with gypsum, and on some old properties its use, with that of sheep manure forked in, has been remarkable in improving the health and productiveness of cacao trees.'

In Grenada, on an experimental plot at Nianganfoix estate, the yield of cacao has been increased, by judicious manuring, from $5\frac{1}{4}$ bags per acre to 8 bags per acre in the four years 1900-4. In St. Lucia, as the result of the establishment of experiment plots, Mr. Hudson reports that the 'planters in that island are now importing basic slag and sulphate of ammonia, and pruning and forking have now become a recognized part of cacao cultivation.'

Experiments with manures carried on in Dominica during the years 1900-5* are summarized by Dr. Watts as follows:—

'Five plots were treated as follows: (1) no manure; (2) basic phosphate and sulphate of potash; (3) dried blood; (4) basic phosphate, sulphate of potash, and dried blood; (5) mulched with grass and leaves. All the manures used proved beneficial. In 1905, the no-manure plot yielded $19\frac{3}{4}$ ℔. of wet cacao per tree; the addition of phosphate and potash resulted in an increase of $2\frac{1}{4}$ ℔. per tree. With dried blood the yield was $24\frac{1}{2}$ ℔., while the combination of dried blood with phosphate and potash brought the yield to $28\frac{3}{4}$ ℔. per tree, being a gain of 9 ℔. over the no-manure plot. This points to the necessity for general manuring in cacao cultivation.'

Careful investigations have been made by the Department officers into the fungoid and insect pests affecting cacao. Two papers on this subject read before the Agricultural Conference at Trinidad are attached.†

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* See *West Indian Bulletin*, Vol. VI, pp. 288-62.—[Ed. *W.I.B.*]

† See *West Indian Bulletin*, Vol. VI, pp. 85-98.—[Ed. *W.I.B.*]

Fruit Industry.

The very considerable fruit trade in Jamaica has been gradually built up during the last twenty-five years. Numerous difficulties had to be overcome, but the nearness of the New York market was an important factor in favour of the industry. Latterly, by means of the Direct Line of steamers, a fruit trade is being established between Jamaica and the United Kingdom. The total value of the fruit trade of Jamaica, in bananas, oranges, and other fruits, is about £1,000,000 annually.

Naturally, the success of Jamaica has led to efforts being made to establish a similar fruit trade in other parts of the West Indies. The Windward and Leeward Islands and Trinidad are 1,000 miles nearer Europe, and several of them are favourably situated for the production of fruit. The only difficulty is in obtaining ships, fitted with cool chambers, which can be depended upon to call on definite dates.

During the last three years the Department has established a trade in shipping bananas by the Royal Mail steamers from Barbados. The kind grown is the Chinese or dwarf banana. Each bunch is packed in a crate, in the same way as is the fruit shipped from the Canary Islands. The prices obtained in the United Kingdom have been uniformly good, and a good demand has arisen for Barbados bananas, which are preferred in the English market to any other. At a conference of banana growers, held on October 13 last, it was stated that, in the year 1902, 18 bunches only were shipped; in 1903 there were shipped 6,693 bunches; in 1904 the shipments amounted to 15,326 bunches; while in 1905 the total shipments amounted to over 40,000 bunches. The first crop may be reaped within fifteen months from the time of planting. Thereafter, a banana field will yield from 300 to 500 bunches per acre, depending on the soil and rainfall. It is stated that the net returns from banana cultivation at Barbados are likely to be from £12 to £20 per acre.*

If suitable facilities could be provided for carrying the fruit, it is probable that fresh tropical fruit, such as bananas, oranges, mangos, avocado pears, and papaws, could be regularly shipped to Europe from British Guiana, Trinidad, Grenada, St. Vincent, Barbados, St. Lucia, and Dominica; also pine-apples from Antigua.

In Trinidad the British West Indian Fruit Company, in which the Royal Mail Steam Packet Company has a controlling interest, was started in 1905. Regular shipments of fruit are now being made from that island.

With the view of developing the fruit industry in the West Indies, the Chairman of the Royal Mail Company gave an undertaking at Barbados on November 13 last, that the company was prepared at once to fit Hall's cold-storage system in the remaining mail steamers connecting with these colonies; also on three new cargo boats within six months or less. In each of the latter the company would provide from 1,000 to 1,500 tons of refrigerated space.

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* See *West Indian Bulletin*, Vol. VI, pp 99-106.—[Ed. *W.I.B.*]

Cotton Industry.

The first of the recent experiments in cotton growing were started at St. Lucia in 1900. In the following year these experiments were extended to Barbados and the Northern Islands. In 1902, Messrs. Sendall and Wade began the cultivation of cotton on a commercial scale at St. Kitt's and Montserrat. The total area planted in all the islands in 1902 was 500 acres. This was increased in 1903 to 4,000 acres. During the year 1904 the area planted in Sea Island cotton was 7,243 acres, and in other varieties 4,438 acres, making a total of 11,681 acres. Valuable assistance was rendered by the British Cotton-growing Association, in making grants of money and machinery; also in taking charge of the shipments of cotton and finding the best market for them. More recently, the association arranged for a visit to the West Indies by Mr. E. Lomas Oliver, who rendered great service by explaining in detail the requirements of spinners in regard to uniformity in length of staple, colour, and fineness. The Imperial Department of Agriculture supplied, at cost price, 35,700 ℔. of seed of the best variety of Sea Island cotton. At present there are fifteen well-equipped cotton ginneries in working order. The prices obtained for West Indian Sea Island cotton during the past season have ranged from 12*d.* to 18*d.* per ℔. The average price was 14½*d.* per ℔. It is now recognized that West Indian Sea Island cotton is an article in good demand, and the industry shows every promise of being established on remunerative lines.*

The following is taken from the annual report of the British Cotton-growing Association for the year ending August 31, 1905:—

'Excellent as were the results obtained in 1904, the cotton produced in 1905 is still more successful. The Imperial Commissioner of the West Indian Department of Agriculture took especial pains to obtain a good supply of a first-class quality of Sea Island seed, and those planters who used this seed have every reason to be satisfied, for the cotton produced is even superior to that grown on most of the best Sea Island plantations in South Carolina, and has realized 2*d.* to 3*d.* per ℔. more than American-grown cotton.'

Further, it is stated: 'The prospects for the coming season are equally good, for there will probably be an increase in the area under cultivation of from 30 per cent. to 50 per cent., and as most of the planters have now realized the importance of the use of carefully selected seed, there is every reason to look to a still further improvement in quality. St. Vincent and Barbados have been the most successful islands; the climate in the latter is more suitable, but the soil in the former is very much superior. Good results have also been obtained in Montserrat, St. Kitt's, Nevis, Antigua, and other islands, but in Jamaica very little has been done. In addition to advantages for our spinners, the re-introduction of cotton

*The prices obtained for West Indian Sea Island cotton during 1906 have been slightly higher than in the previous season, ranging from 14*d.* to 20*d.* per ℔.—[Ed. *W.I.B.*]

cultivation has conferred an undoubted benefit on the West Indies, as it will enable planters to be less dependent on one single article of produce, viz., sugar.'

Three fully-equipped cotton-ginning factories have been erected and worked under the auspices of the Department in St. Vincent, Antigua, and Barbados. In the last-named island the factory has been taken over by the Barbados Co-operative Cotton Factory, Ltd., to be worked on co-operative lines. Similar arrangements are under consideration for the disposal of the factories in Antigua and St. Vincent.

The following is a statement showing the amount and estimated value (furnished by the Customs Department in each case) of Sea Island cotton exported from the various West Indian Colonies (in order of output) for the year ending December 31, 1905* :—

Colony.	Bales.	Weight in pounds.	Estimated value.
Barbados	967	344,232	£17,212
Nevis	724	144,721	7,236
St. Vincent	298	97,152	4,858
St. Kitt's	296	87,080	4,354
Montserrat	170	82,287	4,114
Grenada (Marie Galante)...	704	212,722	2,693
Antigua	296	52,656	2,633
Jamaica	24	4,823	225
Anguilla	163	31,977	1,599
Trinidad (and Tobago) ...	42	12,981	386
Virgin Islands	21	4,100	205
British Guiana	10	1,453	38
St. Lucia	40	1,388	32
Total... ...	3,755	1,077,572	45,585

In December 1904, the British Cotton-growing Association made a grant to provide the services of a Travelling Inspector, to be attached to this Department, in connexion with cotton investigations. This grant has since been renewed for the year 1906.

In addition, in order to encourage the production of cotton of the best qualities, the President of the association (Sir Alfred L. Jones, K.C.M.G.) has offered eleven gold and seventeen silver medals for competition amongst cotton growers during 1906 and 1907.

* A statement showing the amount and estimated value of Sea Island cotton exported from the various West India Islands during the quarter ended March 31, 1906, will be found in the *Agricultural News*, Vol. V, p. 214. This statement shows that 2,285½ bales, or 786,566 lb., of lint were exported during the quarter, the value being estimated at £36,268.—[Ed. *W.I.B.*]

Rice Industry.

During the four years (1897-1901) there were produced in British Guiana a total of 46,747 tons of paddy (unhusked rice), equivalent to 34,141 tons of clean rice, of the approximate value of £370,000.* In the report of the Board of Agriculture for the year 1904-5 it was stated that the area under rice cultivation had undergone a large increase. The total area in 1904-5 was 21,920 acres, as against 16,670 acres in the previous year. The yield of paddy had increased from 17,701 tons to 22,597 tons.

The average yield of paddy in British Guiana on lands properly irrigated and properly drained was stated to be about 28 bags (of 120 ℔. each) to the acre. Such yields, when obtainable, would be exceedingly remunerative to the grower. At the Botanic Gardens crops of selected rice ranged from 15 to 20 bags of paddy per acre.

The industry is evidently destined to became an important one.†

In Trinidad the cultivation of swamp rice has grown rapidly in recent years. According to the Rev. Dr. Morton :**—

'The first favourite is a long-grained rice, called by the East Indian "Joyiya," which seems identical with "Nagra" rice. It is usual to plant all swamp rice in nurseries early in June, and to plant out into the field early in July, but this variety has a tendency in good land to grow very tall and suffer from lodging. To prevent this it is sown more widely in the nursery and kept longer there before replanting. This dwarfs the straw, and thus prevents loss of crop by lodging. The next favourite is called "Mutmuriya," which is short-grained, like "Chitigong." It is less prolific than "Nagra." These two are reaped in October, and spoken of as five months' rice. A third variety ("Jarahar") takes six months to mature. This has a longer grain than "Nagra." It is very prolific, but the top leaf almost surrounds the heavy ear which it helps to support, and, being necessarily cut along with it, gives trouble in cleaning the rice. Other varieties are sweet rice, which smells sweet in the field, in the bag, and on the table; black rice and red rice (two varieties), large Upland rice, twelve weeks' rice, and bearded rice. This last has a long awn, somewhat like bearded barley, which is very useful in defending the grain from the attacks of birds. Thirty barrels of "Nagra" rice in the husk per acre may be taken as a good crop; 24 of "Chitigong" and 15 of Upland rice, which is equal to about half that number of bags when cleaned. In Trinidad native rice is generally sold in the husk. The price at present is $2·00 per barrel, but it varies with the price of imported rice.'

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* In January 1905, Creole rice (ex store) was selling in British Guiana at the rate of $4·25 per bag of 177 ℔. In January 1906, it was selling at the rate of $4·10 per bag of 177 ℔.

† See *West Indian Bulletin*, Vol. VI, pp. 170-2.—[Ed. *W.I.B.*]

** See *West Indian Bulletin*, Vol. VI, pp. 172-3.—[Ed. *W.I.B.*]

Rice is also being grown to some extent in Jamaica and St. Lucia. At the prison farm in Jamaica 3 acres in rice were expected to yield at the rate of 70 bushels per acre. In other districts of the island 145 acres were returned as under rice.

LIME INDUSTRY.

The exports of limes, concentrated lime juice, and essential oils of limes, obtained from the West Indian lime tree, from Dominica are of the annual value of £45,370. Lime juice and oils are exported from Montserrat of the value of £8,090; limes and lime juice from Jamaica of the annual value of about £6,000. Trinidad also exports some lime juice.

This industry has occasionally been threatened by the attacks of scale insects, chiefly the purple scale (*Mytilaspis citricola*) and the orange snow scale (*Chionaspis citri*), both in Dominica and Montserrat. It has been shown at Dominica that these insects can be kept in check by careful cultivation, including pruning and manuring the trees, and the use of insecticides. A small steam outfit for spraying lime trees has been introduced on one estate in Dominica, with satisfactory results.

The manufacture of commercial citrate of lime has been investigated by Dr. Watts, and the results have been published in the *West Indian Bulletin* (Vol. II, p. 308, and Vol. III, p. 152).

The total shipments from Dominica, converted into barrels of fruit, on the bases of a concentration 11 to 1, and of 8 gallons of juice per barrel of fruit are as follows :—

LIME SHIPMENTS.

Year.	Barrels.	Year.	Barrels.
1895...	78,182	1900...	164,806
1896...	88,624	1901...	147,705
1897...	90,837	1902...	220,740
1898...	125,816	1903...	107,883*
1899...	127,556	1904...	153,523

* Blight and gale.

SHIPMENTS OF ESSENTIAL OIL OF LIMES.

——	1899.	1900.	1901.	1902.	1903.	1904.
	Gals.	Gals.	Gals.	Gals.	Gals.	Gals.
Distilled oil of limes...	3,315	3,990	3,299	4,761	2,740	2,261
Otto of limes............	272	456	608	948	310	543

There is a steady demand for West Indian limes in the United Kingdom. The late Colonial and Indian Exhibition, held at the Crystal Palace, proved of considerable service in bringing limes under the notice of the British public and encouraging their more general use instead of lemons.

TOBACCO INDUSTRY.

Increased interest is being taken in this industry, especially in Jamaica, where, in addition to the considerable local consumption, the exports of tobacco, cigars, and cigarettes are of the annual value of £20,000. Experiments in tobacco growing have been carried on for some years in Trinidad, and also in St. Kitt's, Antigua, and St. Lucia.

Shade-grown tobacco for wrappers has latterly been grown in Jamaica and St. Kitt's. The experiments that have been carried on for some years at the Hope Experiment Station, Jamaica, have shown that cigar wrapper tobacco, equal, if not superior, to Sumatra, can be grown in Jamaica. The cost of production has been placed at 2*s.* to 2*s.* 2½*d.* per ℔. Samples of the leaf were estimated by an expert to be worth 6*s.* per ℔. Although these figures are liable to revision, with wider experience in Jamaica and elsewhere, it is evident that the cultivation of this type of tobacco would leave a good margin for profit.

In regard to pipe tobacco, in a letter addressed to the Under-Secretary of State for the Colonies, dated October 21, 1905, the Secretary to the Admiralty states that, with the assistance of Mr. F. V. Chalmers, the Admiralty obtained a supply (1,508 ℔.) of leaf tobacco from Jamaica for trial in the navy; but, as it transpired that this tobacco by itself was not suitable for pipe smoking, and that there is not, at the present time, any colonial-grown tobacco suitable for blending with it, arrangements were made for it to be blended and manufactured with a quantity of Virginian-grown tobacco, the proportion being 1,508 ℔. of Jamaica to 5,075 ℔. of Virginian. This preparation is now undergoing trial in the fleet, and the results of the experiment will be watched with interest.

RUBBER INDUSTRY.

During the last seven years the possibility of establishing rubber plantations in the West Indies has received attention. The first systematic attempts in that direction have been made in Trinidad and Tobago. It is estimated that in the latter island there are about 90,000 trees of the Central American rubber (*Castilloa elastica*) already planted.*

Small numbers of similar trees exist also in Jamaica, Grenada, St. Vincent, St. Lucia, and Dominica, in all of which favourable conditions exist for a rubber industry. In some localities the trees are being used as shade for cacao. Specimens of rubber produced in Dominica and St. Lucia have been favourably reported on, and there is every probability that in districts suited to the growth of the trees large numbers will be

* See *West Indian Bulletin*, Vol. VI, pp. 139-49.—[Ed. *W.I.B.*]

planted during the next few years. Neither the Para rubber (*Hevea brasiliensis*) nor the Lagos rubber (*Funtumia elastica*) has yet been tried on a large scale. In British Guiana an industry is being carried on in rubber obtained from the indigenous trees of *Sapium biglandulosum* and species of *Hevea.*

Sisal Hemp Industry.

Full information in regard to the requirements of this industry has been published in the *West Indian Bulletin* (Vol. V, pp. 150-72). There are large stretches of land in the Leeward Islands well adapted for growing sisal hemp, and the industry would be likely to prove remunerative. The true sisal hemp plant (*Agave sisalana*) is under experimental cultivation in several islands, and the fibre produced has been reported to be of good quality and equal to that produced in Yucatan, Bahamas, and the Turks and Caicos Islands.

The value of the sisal hemp exported from the Bahamas in 1902-3 was £37,574; in 1904-5, £29,557. The value exported from the Turks and Caicos Islands in 1900 was £5,080: in 1901, £6,551; and in 1902, £7,100.*

Rearing of Stock.

Considerable sums have been expended during the last six years by the Imperial Department of Agriculture in the purchase of pedigree animals for the purpose of improving local breeds in the smaller islands. Already there is a distinct improvement noticeable in some localities, especially in small stock, such as sheep, goats, rabbits, and poultry. Dominica has taken up the improvement of riding ponies, and a small stock farm is attached to the Agricultural School in that island. Two fine horses and a Maltese jack have been maintained for several years. Berkshire pigs and poultry have also been introduced. In St. Vincent a stock farm is in course of being established. In the meantime, a pedigree Hereford bull and improved breeds of sheep, goats, pigs, poultry, and rabbits have been introduced to replace, in part, those destroyed by the volcanic eruptions. In Barbados two stud goats, one presented by Baroness Burdett-Coutts, were introduced two years ago. Antigua, the small island of Nevis, and the Virgin Islands have also greatly benefited by the introduction of new stock. At Barbuda the Government of Antigua is proposing to establish a stock-raising farm, and to utilize the large areas of good grass-land hitherto lying waste in that interesting island.

What is known as the Woolless Sheep of Barbados (probably of African origin) has been distributed to the other colonies, where it is regarded as very hardy and profitable. It is not uncommon for well-fed wethers to weigh 120 lb. to 130 lb. (live weight) when about fifteen months old. A number of these sheep have been supplied to the United States Department of Agriculture for trial in the Southern States.†

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* The total quantity of fibre exported during the year 1904 was 463,695 lb., of a value of £6,886.—[Ed. *W.I.B.*]

† See also *West Indian Bulletin*, Vol. VI, pp 187-97.—[Ed. *W.I.B.*]

The appearance of anthrax in certain parts of the West Indies has caused keen interest to be taken in the subject. Trinidad is peculiarly liable to be infected, on account of the regular importation of animals from the adjoining coasts of Venezuela. Recently a serious outbreak of anthrax has appeared in some districts in British Guiana. Sporadic cases have occurred in St. Vincent and Grenada. As shown in the *West Indian Bulletin* (Vol. VI, pp. 156-70), full information has been published as to the nature and treatment of anthrax, and it is hoped that effectual measures will be adopted in all these colonies to keep the disease in check.

Treatment of the Diseases of Plants.

One of the earliest services rendered by the Department to the sugar industry in the West Indies was the discovery of the life-history of the moth borer of the sugar-cane. In some islands and in some years the loss in rotten canes caused by this insect amounted in value to several thousand pounds. Mr. Maxwell-Lefroy, then Entomologist on the staff of this Department, discovered the eggs of the moth borer in 1900. These were deposited in greenish clusters on the under side of the leaf of the sugar-cane, but in such a manner that they had hitherto escaped notice. Afterwards, Mr. Maxwell-Lefroy gave such valuable hints in regard to the manner of dealing with the pest that the sugar-cane borer is now capable of being kept under complete control; as also the weevil borer, root borer, cane-fly, and shot borer. A new insect pest affecting sugar-cane is the larger moth borer of British Guiana. It appeared on one estate only, and its attacks have, fortunately, not been repeated. Other diseases of the sugar-cane dealt with have been rind fungus, pine-apple disease, and the root fungus, all of which have been closely studied and described, so that the planters are favourably placed in dealing with them wherever they make their appearance. Further information in regard to these diseases is given in the *West Indian Bulletin* (Vol. VI, pp. 33-47).

Similar investigation has been carried on in regard to the fungoid and insect pests affecting cacao trees in Trinidad, Grenada, St. Lucia, Dominica, and Jamaica. 'Canker' and 'die-back,' 'brown rot,' and 'pod rot,' 'thread blight,' and the 'Witch Broom' disease of Surinam are some of the fungoid diseases dealt with. The chief insects that have been found to affect cacao trees are the cacao beetle and cacao thrips. The former is generally distributed throughout the West Indies and the northern parts of South America. The latter was first reported as a serious pest to cacao at Grenada in 1898.*

Cotton is seriously attacked by such fungoid diseases as rust, leaf spot, leaf mildew, anthracnose, and black boll. The chief insect pest is the cotton worm, sometimes causing serious damage, and if neglected causing the entire destruction of the crop. It has been conclusively proved that prompt treatment with Paris green is an effective protection against the cotton worm. Other insect pests are the cotton stainer, red maggot,

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* See *West Indian Bulletin*, Vol. VI, pp. 85-98.—[Ed. *W. I. B.*]

leaf-blister mite, and boll weevil. The beneficial insects found on cotton are two kinds of lady-birds that prey on the cotton aphis, and the 'wild bees' and 'cow bees' (*Polistes*) and other wasps which prey on the caterpillar of the cotton worm.*

The cocoa-nut palms in the West Indies have lately been attacked by a serious disease known as 'Bud-rot.'† This came into prominence in Cuba in 1891, and it has since caused anxiety in Jamaica, Trinidad, and British Guiana. Owing to the prevalence of this and other diseases, the prospects of the cocoa-nut industry in the West Indies, at present, are not so favourable as could be desired, but, provided that energetic and concerted action is taken by those concerned, and the directions issued by the Department are closely followed, serious apprehension need not be felt as to the ultimate results.

With the view of preventing the introduction of further insect and other pests into the West Indies, the Department has taken an active part in securing the fumigation of all imported plants. The practice is now general in all the leading colonies. No difficulty was experienced in carrying this out, as public opinion had already been educated in its favour, so that with the hearty co-operation of the planting community there has now been established an important means for keeping out insect and other pests, and thus protecting agricultural interests in the West Indies.

Agricultural Teaching.

Some of the results of the considerable attention that has been devoted by the Department to encouraging the teaching of the principles of agriculture in the colleges and schools in the West Indies are on record in the *West Indian Bulletin*, Vol. VI, pp. 197-237.

In regard to the work carried on at Harrison College, Barbados, the late Head-master (Mr. Horace Deighton, M.A., F.R.A.S.), in a paper read before the Agricultural Conference in Trinidad, stated very fully the advantages that are being derived from the systematic teaching of science at this and similar colleges. Mention might also be made of the successful working of the Agricultural Schools maintained by the Department in St. Vincent, St. Lucia, and Dominica for training boys in the details of garden and field work, so as to fit them to start life as settlers on Crown lands and as foremen, overseers, or assistant managers of sugar, cacao, rubber, and cotton estates. There is also the testimony of the Inspectors of Primary Schools, commenting on the success of the steps taken to train the teachers in agricultural subjects and the general advance that has taken place, of late years, in introducing such subjects into the curriculum of the schools and in securing practical agricultural work by means of school gardens.

There are also to be noticed the popular agricultural knowledge that has been disseminated among all classes of the

* See *West Indian Bulletin*, Vol. VI, pp. 117-29.—[Ed. *W. I. B.*]
† See *West Indian Bulletin*, Vol. VI, pp. 307-21.—[Ed. *W. I. B.*]

community by means of the travelling agricultural instructors, and the efforts of the Department in its relations with the agricultural societies and in promoting agricultural shows, at which prizes and diplomas are offered for competition.

Agricultural Publications.

The Imperial Department of Agriculture issues a popular fortnightly review entitled the *Agricultural News* and a quarterly scientific journal, the *West Indian Bulletin*. Both these publications have a wide circulation amongst members of the planting community. In addition, there are issued pamphlets on special subjects and annual progress reports on the several Botanic and Experiment Stations, the Agricultural Schools, and Agricultural Education. The total number of copies of publications issued by the Department during the year 1904 amounted to 76,200.

Imperial Value of the Department.

Recent experience has shown that the Imperial Department of Agriculture is serving a useful purpose as a leading school of tropical agriculture. It issues, as already stated, from 50,000 to 70,000 copies of publications every year, and these are widely circulated in the West Indian Colonies and in other British possessions in the tropics of both the Old and New World. It is acknowledged that there is no other organization in any part of the tropics where such diversified work is carried on over so large an area and under such varying conditions of soil and climate. The total area of the British possessions in this part of the world in which the Department is interested is 116,451 square miles, with total exports of the annual value of £6,102,000. Hence, it is possible to afford a sound, scientific, and practical training to students in the cultivation of crops suited to nearly all tropical conditions. Experiment stations are maintained for practically testing crops at different elevations, as well as in dry and wet districts. Further, the results are tabulated year by year, reviewed, as compared with the results in previous years and in other countries, and placed within reach of those interested in such a manner as to be readily understood and acted upon.

Amongst the capable scientific men who have been trained under the Imperial Department of Agriculture during the last seven years, and holding appointments elsewhere, are the following :—

Entomologist to the Government of India, Mycologist to the Government of India, Assistant Director of Agriculture in British East Africa, Superintendent of Agriculture in Fiji, Assistant Director of Vegetable Pathology, Hawaiian Islands, Superintendent of Economic Collections at the Imperial Institute, London.

Arrangements are also under consideration for supplying cotton experts, assistant chemists for sugar factories, and foremen in charge of cacao, rubber, and other plantations. It is anticipated that the demand for such specially trained men will

steadily increase. Every effort is therefore being made to supply them. The diversified character of the cultivations carried on in the West Indies affords ready means for training such men. In fact, the resources of the Department in this respect have been declared by a competent authority to be unique.

Indirect Value of the Department.

One of the most gratifying features connected with the work of the Department is the steady growth of appreciation of its value 'in uplifting the several colonies into the view of one another and into the view of the Mother Country and her markets and capitalists.' This is particularly shown on such occasions as the West Indian Agricultural Conferences, where leading men, possessing a direct interest in the welfare of these colonies and representing the practical side of agriculture, cordially co-operate with the officers of the Department in solving the complex and often difficult problems submitted for their consideration.

The success of these conferences has probably done more than anything else to bring the Department into sympathy with all sections of the community.

As well stated by Dr. Watts: 'Of more importance than all are the changes induced insensibly in the members of the community generally. The work of the trained officers of the Department, by its constant, steady operation, has a wider and deeper influence than an uninterested observer may imagine. Under this influence ideas are stimulated, good ones encouraged and faulty ones corrected or disposed of, so that there results a general progressive tendency, the origin of which cannot be readily or definitely traced, but which in its result upon the welfare of a community is perhaps of equal, or even greater, importance than the conscious, definite efforts of the Department.'

I have, etc.,

(Sgd.) D. MORRIS.

THE POLARIMETRIC DETERMINATION OF SUCROSE.

BY FRANCIS WATTS, C.M.G., D.Sc., F.I.C., F.C.S., and

H. A. TEMPANY, B.Sc. (Lond.), A.I.C.

PART II.

In a previous paper we discussed the effect of temperature on the polarimetric determination of sucrose, and also the effect of the volume of the lead precipitate produced in the process of clarifying saccharine solutions for optical examination. (See *West Indian Bulletin*, Vol. VI, pp. 52-60.)

In that paper we produced evidence to support the conclusion that temperature exercises such an influence upon the optical activity of sucrose as to render it desirable and necessary to introduce a correction for this effect when working under tropical conditions. (The results there arrived at in this connexion were dependent upon the purity of the specimen of sugar upon which the work was performed.)

The paper in question has been the subject of criticism in the *International Sugar Journal* (Vol. VII, pp. 419 et seq., Wiechmann, and pp. 527 et seq., Messrs. H. and L. Pellet). These were followed by an editorial summing up of the work done by various observers (Vol. VIII, pp. 10 et seq., January 1906), which concludes with the expression : 'Where experts disagree, who shall decide? One subject of dispute may be dismissed in a few words. The influence of temperature on the optical activity of sucrose is a question to be decided by experimental evidence alone. Experts do not express opinions regarding probabilities, but regarding the nature of the evidence brought forward. Where many experimental difficulties exist, criticism is of the greatest value in avoiding errors, and thus ultimately arriving at the truth. We must hope that the investigations now in progress will furnish more definite information regarding this supposed influence of temperature.'

In these discussions one valid objection is raised, namely, that the correction for temperature proposed by us presupposes that the specimen of sugar used in our determinations was absolutely pure sucrose—a point difficult of proof.

It is possible, however, to devise a method eliminating this objection. To this end it is only necessary to observe the optical activity of a solution of sucrose at two different temperatures and to compare the results. Various corrections have to be made for the effect of temperature upon the quartz wedge of the polarimeter and upon the volume of the solution, but the factors for these corrections have been determined with a high degree of precision.

Unfortunately, this method of solving the problem presents special difficulties in the tropics and was therefore set aside as inapplicable when we were first attacking the question. It is, however, one which can be applied with less difficulty in a cold

climate. Accordingly, advantage was taken of the presence of one of us (H. A. T.) in England during last winter to make a series of observations on these lines.

The object in view was to determine, at two widely different temperatures, the polarimeter readings of a solution containing 26 grams of sugar in 100 c.c., to make corrections for the effect of temperature upon the volume of the solution and upon the quartz wedge, and to ascertain whether the readings thus corrected revealed any difference; if so, the difference would be held to be due to a change in the optical activity of sucrose consequent upon the change in temperature.

It is to be observed that in this method the purity of the sugar is of little consequence, provided that no large amount of any other substance is present which may also be liable to change of activity with changing temperature: as a matter of fact, the purest obtainable sugar was employed. The observations all being made on one solution, any possible errors in weighing or measuring are eliminated. Minor errors or want of adjustment of the polarimeter do not affect the accuracy, for the point to be observed is only a difference over a very small range of the polarimeter scale, in the case in question about 1° Ventzke.

The experiments were performed in the laboratory of Messrs. Garton Hill & Co., of Battersea, London, whose chief chemist, Dr. L. T. Thorne, and his staff took a lively interest in the investigation and afforded much useful assistance.

A preliminary series of experiments was performed in order to ascertain the best working condition and to ensure everything being in order. The room in which the experiments were performed was a small one, about 10 feet by 10 feet square.

The arrangement for heating the room consisted of two Erlenmeyer combustion furnaces mounted on an iron plate in the middle of the room.

Polarimeter.—The polarimeter used was a white light double quartz wedge compensation instrument, of the half shadow type, by Schmidt and Haensch, and standardized by them.

Polarimeter lamp.—An ordinary polarimeter lamp for gas was used, with lens, chimney, etc. This lamp was enclosed in a wooden box lined with asbestos card, a circular hole being cut in the side opposite the lens. This was done to obviate any heating effect of the lamp on the polarimeter and tube. With the above arrangement it was found that the temperature remained unaltered during the taking of the readings.

Polarimeter tube.—The polarimeter tube used was of glass with a tubulure admitting of a thermometer being passed into the liquid. The diameter of the tube was large, about 1½ cm., and the length 220 mm. The capacity of the tube was about 50 c.c. The tube had been expressly made for invert sugar determinations by heating, and was quite the most suitable obtainable. The fact that the tube with the cane sugar solution gave a reading greater than 100 did not matter, as the double

quartz wedge of the polarimeter permitted of readings higher than 100° V. being obtained.

The tube was fitted with a thermometer, accurately graduated in fifths of a degree Centigrade, which, passing through a tightly fitting cork, obviated any risk of evaporation. The tube was enclosed in a copper air-bath, thus obviating sudden changes of temperature.

Temperature.—The temperature of the solution was ascertained, as already stated, by a thermometer passing into the solution. A second thermometer was placed between the quartz wedges, so as to give as near an indication of the temperature at that point as possible. Both of these thermometers were graduated to read to ·2° C. A third thermometer was placed inside the air bath near the polarimeter tube. Several other thermometers were distributed round the room, so as to enable the average air temperature of the room to be satisfactorily ascertained.

Sugar.—The sample of sugar used in these experiments had been prepared by precipitation from a concentrated aqueous solution by the addition of alcohol. Before using it was kept in an evacuated desiccator for forty-eight hours.

In making up the solution 65 grams of sugar were weighed out, dissolved in distilled water, and the solution made up to 250 c.c. in a graduated flask.

Experimental details and results.—The apparatus, etc., required, having been obtained, the whole was allowed to remain over from Saturday afternoon till Monday morning.

The first thing on Monday morning the sugar solution was made up, as detailed above, at the room temperature (filtered once through Swedish paper), and the polarimeter tube washed out and filled with solution. The remainder of the solution was preserved in a well-stoppered flask in the room in which the experiments were performed. The solution was then polarized.

SERIES I.

READINGS IN 220 MM. TUBE.

a.	b. (Zero reset.)
109·8	109·9
109·8	109·9
109·9	110·0
109·9	109·85
109·9	109·9

Mean = 109·885

Reduced to terms of 200 mm. tube = 99·898

Temperature of solution.	Temperature near quartz wedge.
Initial 16·1°C.	Initial 15·6°C.
Final 16·2°C.	Final 16·4°C.
Mean 16·1°C.	Mean 16·0°C.

After this first series of readings had been taken, the heating of the room was commenced. This, as already stated, was accomplished by means of two combustion furnaces. These were lighted, and the temperature of the air rose rapidly; that of the solution in the tube followed more slowly. The heating was continued till the air temperature stood at about 37°C., the solution then being at about 29°C.; the gas supply was then reduced, and the air temperature allowed to fall slowly, that of the solution continuing to rise slowly. When the temperatures of the air and the solution were approximately coincident, the gas supply was increased, so as to maintain the temperature of everything constant: after this uniform condition had been maintained for ten minutes, the second series of readings was taken.

The entire process of heating up occupied about two hours.

The results obtained were as follows:—

SERIES II.

READINGS BY H. A. T.

	(Zero reset.)
a. 108·8	b. 108·9
108·8	108·9
108·8	108·75
108·75	108·8
108·8	108·8

Mean = 108·810

READINGS BY L. T. T.

a. 108·75	b. 108·75
108·75	108·8
108·8	108·8
108·8	108·75

Mean = 108·775

Mean of all readings ... ... = 108·792

Reduced to terms of 200 mm. tube = 98·901

Temperature of solution.	Temperature near quartz wedge.	Temperature of air bath.
Initial 32·8°C.	Initial 33·0°C.	Initial 33·0°C.
Final 32·8°C.	Final 33·0°C.	Final 33·0°C.

After this series of readings had been completed, the tube was emptied and refilled with a fresh portion of solution from the bulk in the stoppered flask, which had been kept in the observation room and thus subjected to the change of temperature, the tube was allowed to stand in the polarimeter for about fifteen minutes so as to ensure uniform temperature conditions, after which a further series of readings was taken with the following results:—

SERIES III.

	(Zero reset.)
a. 108·9	b. 108·7
108·7	108·8
108·8	108·9
108·9	108·8
	108·9

Mean = 108·82

Reduced to terms of 200 mm. tube = 98·929

Temperature of solution.	Temperature near quartz wedge.	Temperature of air bath.
Initial 32·7°C.	Initial 33·2°C.	Initial 32·9°C.
Final 32·7°C.	Final 33·4°C.	Final 33·2°C.

Finally, the polarimeter tube and solution were allowed to stand till the following morning, by which time the temperature had assumed a value approaching nearly to the original, and a further series of readings was taken. These readings were taken by Dr. Thorne and his assistant the following day: H. A. T. was not present when they were taken :—

SERIES IV.

READINGS.

a. 109·75	b. 109·8	c. 109·8
109·75	109·85	109·85
109·8	109·75	109·75
109·75	109·85	109·85
...	109·75	109·85
...	...	109·8
...	...	109·75

Mean = 109·790

Reduced to terms of 200 mm. tube = 99·809

Temperature, commencement 17°C.

„ end 18°C. Mean 17·5°C.*

*Temperature near quartz wedge not recorded : it is assumed to have been that of the solution.

This result is of importance as showing that the lowering observed was not due in any way to inversion.

We thus have the following readings from observations made on a single solution :—

(1) at 16·1°C. = 99·898 (2) at 32·8°C. = 98·901
(3) at 32·7°C. = 98·929 (4) at 17·5°C. = 99·809

Consideration of results obtained.—

Four factors must be taken into account in considering the lowering of the polarimetric reading observed with rise of temperature :—

a. Expansion of the sugar solution.*
b. Influence of rise of temperature on the specific rotation of the quartz wedge.
c. Expansion of polarimeter tube.
d. Influence of rise of temperature on the specific rotation of sucrose.

As already stated, we have four sets of readings based on one solution, two at low and two at high temperatures.

These afford four comparisons, namely, the difference between 1 and 2 ; 1 and 3 ; 4 and 2 ; 4 and 3.

---

* As the expansion of the sugar solution with the rise of temperature has an important influence upon the observed readings, it was deemed desirable to determine exactly the co-efficient of expansion of a sugar solution containing 26 grams per 100 c.c. through about the same range of temperature as that observed while making the polarimeter readings. This was found to be ·00029 per degree Centigrade.

The method adopted was that of the 'weight thermometer' with precautions to prevent evaporation during weighing. In order to ensure accuracy, a large volume of solution was employed. The following results were obtained :—

Weight of vessel and solution at 16·5 ° C.	...	254·4514 grams.
Weight of vessel	...	76·8528 ,,
Weight of solution at 16·5 ° C. ...	...	177·5986 ,,
Weight of vessel and solution at 28 0 ° C.	...	253·9076 ,,
Weight of vessel	...	76·8528 ,,
Weight of solution at 28 ° C.	...	177 0548 ,,
P = Weight of solution at 16·5 ° C. ...	...	
p = difference between weight at 16·5 ° C. and 28 ° C.	...	·5438 ,,
P − p = weight of solution at 28 ° C.	...	
= difference of temperature, or 11·5 ° C. ...	...	

$$\text{Apparent expansion} = \frac{p}{(P\text{-}p)\ t} = \frac{\cdot 5438}{177\cdot 0548 \times 11\cdot 5}$$
$$= \cdot 0002677$$

To this must be added the co-efficient for the expansion of glass in order to obtain the real co-efficient of expansion of the solution.

Apparent expansion of solution	... ...	·0002677
Expansion of glass ...	... ...	·0000258
		·0002935

Whence the co-efficient of expansion per degree Centigrade of a solution of sucrose containing 26 grams per 100 c.c. is taken at ·00029, a figure agreeing with that given by Landolt.

Taking the comparison between series 1 and 2, we find as follows :—

A rise of temperature of 16·7° for the solution and 17·0° for the quartz wedge. This is accompanied by a lowering of the polarimeter reading of ·997° V.

Correction for expansion of liquid ·00029 × 16·7 × 98·901	= + ·479° V.
Correction for temperature quartz wedge (Jobin) ·00016 × 17 × 98·901	= + ·269° V.
Correction for expansion of polarimeter tube ·0000086 × 16·7 × 98·901	= – ·014° V.
	·734° V.

Observed difference	·997° V.	
Difference accounted for by corrections	·734° V.	
" " " " sucrose	·263° V.	
Whence the difference due to 1°C. is		·0157° V.

Taking next the comparison between 1 and 3—

We have a difference of temperature of 16·6°C. for the solution, and 17·1°C. for the quartz wedge, with a difference of ·969° V in the polarimeter readings.

Correction for expansion of liquid ·00029 × 16·6 × 98·929	= + ·476° V.
Correction for temperature quartz wedge (Jobin) ·00016 × 17·1 × 98·929 ...	= + ·271° V.
Correction for expansion of polarimeter tube ·0000086 × 16·6 × 98·929... ...	= – ·014° V.
	·733° V.

Observed difference	·969° V.	
Difference due to corrections ...	·733° V.	
Difference due to sucrose	·236° V.	
Whence difference for 1°C. is ...		·0142° V.

Taking next the comparisons between 3 and 4—

We have a difference of temperature of 15·2°C. for the solution, and 15·7 for the quartz wedge, with a difference of ·88° V. in the polarimetric reading.

Correction for contraction of liquid ·00029 × 15·2 × 98·929	= + ·436° V.
Correction for temperature quartz wedge (Jobin) ·00016 × 15·7 × 98·929	= + ·248° V.
Correction for expansion of polarimeter tube ·0000086 × 16·7 × 98·901	= – ·013° V.
	·671° V.

Observed difference	·880°V.	
Difference due to corrections ...	·671°V.	
Difference due to sucrose	·209°V.	
Whence difference due to 1°C. is ...		·0138°V.

Taking, finally, series 2 and 4—

We have a difference of temperature of 15·3 for solution, and 15·5°C. for quartz wedge, with a difference of ·908 in the polarimeter readings.

Correction for expansion of liquid ·00029 × 15·3 × 98·901	=	+ ·439°V.
Correction for temperature quartz wedge (Jobin) ·00016 × 15·5 × 98·901	=	+ ·245°V.
Correction for expansion of polarimeter tube ·0000086 × 16·7 × 98·901	=	– ·013°V.
		·671°V.

Observed difference	·908°V.	
Difference due to corrections ..	·671°V.	
Difference due to sucrose	237°V.	
Whence difference due to 1°C. is		·0155°V.

Thus for this sugar solution which at 16·1°C. polarizes 99·9, we get the following four figures as a temperature co-efficient for change of rotation per degree C. in degree V. :—

a.	·0157°V.
b.	·0142°V.
c.	·0138°V.
d.	·0155°V.
Mean	·0148°V.

We may therefore state the formula for the correction for the effect of temperature on sucrose as (·000148 t) N, where t is the difference between the observed temperature and 17·5°C., and N the observed polarimeter reading; or, combining this with the correction for the effect of temperature on the quartz wedge (Jobin), and on the polarimeter tube, (·00032 t) N.

This correction for the effect of temperature on sucrose as found by this new series of observations is smaller, by ·00007, or about one-third, than that previously found, but we think that these observations, from which any question as to the purity of the sugar employed is eliminated, remove any doubt as to the fact that change of temperature does affect the optical activity of sucrose, and that it is desirable and necessary to introduce a correction for this when working under tropical conditions.

The difference between the result now obtained and that deduced from our previous experiments may doubtless be regarded as caused partly by errors of observations, inherent in work of this kind, and partly by a trace of impurity in the sugar employed.

We desire to express our sincere thanks to Messrs. Garton Hill & Co., for the use of their laboratory, and to Dr. Thorne

and his staff for their kind interest and assistance, without which the work could not have been carried out.

In conclusion we may point out that the results now put forward by us are in very close agreement with those of Wiley and of Schönrock.

Wiley (*Jour. Amer. Chem. Soc.*, 1899, 21, pp. 568-96. Abstract in *Jour. Chem. Soc. Lond.*, 1999, A ii, p. 702) puts forward results from which the correction to be applied on account of the change of optical activity of sucrose with change of temperature is ·00016 per degree Centigrade for each degree V., the solution being polarized at the temperature at which it is made up. To this must be added the correction for the temperature of the quartz wedge, ·00016, making a total correction of ·00032.

Schönrock, who appears to have been provided with appliances of the greatest accuracy, and who bases his work on observation made both by means of 'polariscopes' and 'polarimeters,' gives as his latest results (*Zeit. Ver. deut. Zucker Ind.*, 1903, 569, pp. 650-3) the following :—

'In practice, if a normal sugar solution is made up at 20°C. but polarized at t° in a saccharimeter, the quartz wedge compensator of which is also at t°, the reading Ventzke must be increased by 0·061 (t–20) in order to obtain the true hundred point of the scale at 20°.' (*Jour. Chem. Soc. Lond.*, 1903. Abstracts ii, p. 764.) This correction includes that for the expansion of the solution with change of temperature and for the lengthening of the saccharimeter tube, corrections which, as stated in our work, amount to ·030. If we deduct this we find Schönrock's correction, applicable to a solution when polarized at the temperature at which it is made up. amounts to ·061 – ·030 = ·031 (t–20) when the saccharimeter reads 100°V., which is in agreement with our results.

Wiley's correction	=	Pol. +	(·00031t)	N.
Schönrock's ,,	=	Pol. +	(·00031t)	N.
Watts and Tempany, present result	=	Pol. +	(·00032t)	N.

Therefore, having regard to the conditions conducing to accuracy under which Schönrock's work was performed, and considering the practical identity of our own and Wiley's results with his, we now suggest the adoption of the following correction for temperature :—

Polarize at the temperature at which the solution is prepared and correct for temperature by the formula, polarization + (·00031t) N, where t is the difference between the temperature of observation and that at which the instrument was standardized, and N is the Ventzke scale reading.

THE MANUFACTURE OF JAMAICA RUM.

The following report on the manufacture of Jamaica rum, by Mr. Charles Allan, B.Sc., Fermentation Chemist, Jamaica, appears in the Report on the work of the Sugar Experiment Station for the year 1905 :—

As a preliminary to investigating the conditions of rum manufacture, I visited, in the end of 1903, and during 1904, a number of estates as representing the manufacture of the various grades of rum produced in the island. I spent December 1903, at Cinnamon Hill, in St. James, and the following January at Denbigh estate, in Clarendon. On those estates I made myself acquainted with the process of making what is called 'Common Clean' rum. In February I went to Trelawny, and, making Cambridge estate my headquarters, I endeavoured to become familiar with the methods adopted in the manufacture of flavoured rum.

Afterwards I made short visits to the estates in Westmoreland, St. Catherine, and St. Ann's.

From those visits I learned the methods followed on the estates, and obtained a general idea of the problems which had to be faced in making such an investigation as I had undertaken.

The first and one of the most interesting of the problems which had to be solved was what constituted the difference between 'common clean' rum and the high-flavoured rum known as 'German rum.'

The prevailing idea seemed to be that the flavour of those rums was due to the essential oils in the cane, and the fact was put forward, as supporting this theory, that all estates, with one exception, which had been successful in producing this class of rum, were northside estates and ratooning estates.

On comparing the methods of manufacturing 'common clean' and high-flavoured rum, one could not but come to the conclusion that either the round-about process used in making high-flavoured rum was unnecessary, or the theory that the flavour was due to the essential oils in the cane was at fault.

On returning from visiting the estates, two samples of rum were sent to me to the laboratory from a northside estate with the request that I should find out by analysis the difference between the samples, as one sample had fetched a considerably higher price than the other. The sample of higher value was from the 1904 crop, the other sample from the previous crop and was an average of what the estate had formerly produced.

The only marked difference in the analyses of these samples was in the compound ethers and in the acidity. It seemed highly probable, therefore, that the enhanced value of the 1904 sample was due to the increase in the compound ethers which amounted to 165·5 parts per 100,000 of absolute alcohol.

The analyses, which were interesting and have proved of considerable importance, were:—

Sample.	In parts per 100,000 of Absolute Alcohol.				Alcoholic strength. Per cent. over proof.
	Ethers.	Acidity.	Aldehydes.	Furfurol.	
1903	344·9	21·6	11·5	0·45	38
1904	510·4	36·0	10·0	0·31	38

Analyses of a large number of rum samples were made and a comparison of the data will clearly show that flavoured rums have a much higher compound ether content. (See pp. 143 and 144.)

From this list the very high ether content is most striking, but the variation from the lowest to a highest is the most noteworthy feature.

Taking a general view of the rums produced in the island, as grouped under the different parishes, it will be observed that the parishes which are noted for the high-priced rums lead easily in the amount of ethers produced.

Trelawny comes first, while Westmoreland is second.

High ether rums are not confined to any one parish, but, without exception, wherever a rum is found which contains over 1,000 parts of ethers, that rum invariably commands a high price in the market.

The evident conclusion is, that a high ether content is an essential feature of high-priced rums. It does not follow that the quantitative amount of ethers alone determines the value of the rum. The proportions in which the various ethers are blended is a most important factor.

How this large amount of ethers is produced, and why it could be produced on some estates and not on others, next engaged our attention. A comparison of the method of manufacture and an examination of the materials used in the distilleries are instructive.

On estates making 'common clean' rum. the method adopted is simplicity itself, when compared with the complicated manipulation required for making high-flavoured rums.

The 'common clean' process consists, in general terms, in mixing together dunder, molasses, and skimmings in proportions which are considered, in the experience of the distiller, to give best results. There are many exceptions to this simple formula. Some allow the skimmings to stand in tanks and so become sour, while others use what are termed trash cisterns. These cisterns are filled with cane trash and the skimmings are run on to this and allowed to soak through. These devices have all the same end in view, namely, the production of acid.

Parish.	Per 100,000 parts Abs. Alcohol.	
	Ethers as ethyl acetate.	Acidity as acetic acid.
St. Andrew.	287·0	50·2
,,	269·0	47·4
,,	229·2	277·5
,,	224·0	81·3
St. Ann.	968·0	7·2
St. Catherine.	209·0	53·0
,,	209·6	29·03
Clarendon.	271·1	55·7
,,	228·2	29·1
,,	196·0	4·0
,,	238·5	18·6
,,	352·0	24·0
,,	517·44	4·8
,,	327·36	19·20
,,	209·8	17·3
,,	286·5	32·8
,,	242·08	7·2
,,	299·2	9·60
,,	1,056·0	12·0
St. Elizabeth.	204·16	9·60
Trelawny.	792·0	28·8
,,	959·2	24·0
,,	1,320·0	44·4
,,	1,020·8	14·4
,,	674·46	43·9
,,	1,267·2	31·2
,,	1,302·4	7·2
,,	1,417·6	24·0
,,	302·72	21·6
,,	415·36	12·0
,,	281·6	8·4
,,	985·6	16·8
,,	862·4	48·0
,,	1,126·4	9·6
,,	1,091·2	14·4

Parish.	Per 100,000 parts Abs. Alcohol.	
	Ethers as ethyl acetate.	Acidity as acetic acid.
Trelawny (*Continued*).	985·6	9·6
”	1,284·8	12·0
”	520·96	28·8
”	1,073·6	14·4
”	1,408·6	4·8
St. James.	582·5	55·7
”	339·6	50·9
”	773·0	94·2
”	1,462·0	169·01
”	862·0	28·8
”	344·96	21·6
”	510·4	36·0
”	492·8	31·2
”	580·8	31·2
Westmoreland.	292·16	21·6
”	289·2	16·9
”	214·4	8·3
”	632·6	10·4
”	455·3	17·0
”	506·9	11·5
”	360·1	27·5
”	299·2	27·0
”	398·7	20·7
”	373·0	26·9
”	524·0	6·7
”	398·2	5·8
”	519·9	7·7
”	220·5	26·5
”	389·7	48·8
”	656·5	20·7
”	456·5	29·17
”	453·0	10·4
”	373·46	19·0
”	205·0	16·0
”	401·28	32·89

The gravities of the wash as set up vary within wide limits, but are generally lower than those used in making flavoured rum. The time taken for the wash to ferment is much less in making 'common clean' than flavoured rum.

A general outline of the process of manufacturing flavoured rum is as follows:—

The wash is set up with skimmings, dunder, molasses, acid, and flavour.

Acid is made by fermenting rum cane juice which has been warmed in the coppers. To this juice is added dunder and sometimes a little skimmings. When fermentation is about over, the fermented liquor is pumped on to cane trash in cisterns and here it gets sour. Into these cisterns sludge settling from the fermented wash is from time to time put. This acid, when considered fit for use, smells like sour beer. Flavour is prepared by running fermented rum cane juice into cisterns outside the fermenting house along with cane trash and dunder which has been stored from the former crop. Generally a proportion of liquid from what is called the 'muck hole' is also added to this cistern. The components of the 'muck hole' are the thicker portion of the dunder from the still, the lees from the retorts, and cane trash, and other adventitious matter which from time to time finds its way into this receptacle. From this cistern the incipient flavouring material passes on to a second and third cistern filled with cane trash, and to which sludge from fermented wash has been added. From the third cistern it is added to the wash. Skimmings are run from the boiling-house into cisterns half filled with cane trash. This is allowed to remain for four, five, or six days. When the skimmings are considered ripe, the wash is set up with them. Fermentation lasts seven to eight days. The time which elapses between setting up the wash and distillation is from thirteen to fourteen days.

As in the case of the 'common clean' process there are many modifications introduced by the distiller, but the foregoing holds good as a general description.

A comparison of the analytical data of distillery materials brings out a very noticeable difference in the amount of acid produced by the two processes.

The analyses of these fermentation products from Jamaica distilleries were made by Mr. A. Sime, late Assistant Chemist to the Experiment Station.

FERMENTATION PRODUCTS.

Nos.	Description.	Brix.	Total sugars.	Total acidity as sulphuric.	Volatile acidity.	Alcohol as proof spirit. Per cent.
1	Cane juice tempered ...	16 96	15·38	...	...	...
2	Skimmings (fresh) ...	17·76	3·13	0·098	...	...
3	Molasses	68·80	61·54	...	..	...
4	Dunder	18·19	0·14	3·33	0·186	...
5	Dunder (old last year)	23·88	0·19	3·185	0·282	0·7
6	Rum cane juice (fermented)...	4·33	0·40	2·60	0·367	8·54
7	Acid, No. 2 cistern ...	5·06	0·59	2·60	0·360	7·08
8	Dead liquor	10·02	0·46	2·45	0·300	13·52
9	Skimmings and dunder (no flavour)...	17·74	4·12	2·245	0·260	4·72
10	Liquor with acid ...	22·27	3·63	1·813	0·210	...
11	Dead wash bottom ...	10·53	0·235	4·70	0·31	14·32
12	Acid ready for use ...	5·60	0·424	2·45	0·68	...
13	Skimmings ready for use...	12·97	1·25	2·74	0·46	...

MOLASSES.

Glucose	—	10·87 per cent.
Sucrose	—	38·39 ,, ,,
Total sugars	—	51·28 ,, ,,
Glucose	—	12·00 ,, ,,
Sucrose	—	33·25 ,, ,,
Total sugars	—	47·00 ,, ,,
Brix	—	70·00 ,, ,,
Glucose	—	11·11 ,, ,,
Sucrose	—	51·10 ,, ,,
Total sugars	—	64·90 ,, ,,

MOLASSES.—(*Continued.*)

Brix	—	69·90	per cent.
Glucose	—	11·76	,, ,,
Sucrose	—	52·15	,, ,,
Total sugars	—	66·66	,, ,,
Brix	—	70·10	,, ,,
Glucose	—	4·34	,, ,,
Sucrose	—	54·43	,, ,,
Total sugars	—	—	
Brix	—	48·17	,, ,,
Glucose	—	12·50	,, ,,
Sucrose	—	29·69	,, ,,
Total sugars	—	43·75	,, ,,
Brix	—	77·36	,, ,,
Glucose	—	29·00	,, ,,
Sucrose	—	34·14	,, ,,
Total sugars	—	64·94	,, ,,
Brix	—	22·500	,, ,,
Glucose	—	31·395	,, ,,
Sucrose	—	55·550	,, ,,
Total sugars	—	10·400	,, ,,
Brix	—	83·30	,, ,,
Glucose	—	19·23	,, ,,
Sucrose	—	54·69	,, ,,
Total sugars	—	76·80	,, ,,
Brix	—	71·56	,, ,,
Glucose	—	21·26	,, ,,
Sucrose	—	43·13	,, ,,
Total sugars	—	66·66	,, ,,
Brix	—	71·24	,, ,,
Glucose	—	18·52	,, ,,
Sucrose	—	41·80	,, ,,
Total sugars	—	62·50	,, ,,
Glucose	—	14·28	,, ,,
Sucrose	—	49·76	,, ,,
Total sugars	—	66·60	,, ,,
	A. 1.		
Brix	—	83·90	,, ,,
Glucose	—	16·94	,, ,,
Sucrose	—	45·59	,, ,,
Total sugars	—	64·93	,, ,,
	A. 1. x.		
Brix	—	84·83	,, ,,
Glucose	—	18·86	,, ,,
Sucrose	—	41·46	,, ,,
Total sugars	—	62·50	,, ,,

MOLASSES.—(*Concluded.*)

Brix	—	69·80	per cent.
Glucose	—	7·40	„ „
Sucrose	—	52·34	„ „
Total sugars	—	62·50	„ „
Brix	—	69·24	„ „
Glucose	—	13·33	„ „
Sucrose	—	44·87	„ „
Total sugars	—	60·56	„ „
Brix	—	78·32	„ „
Glucose	—	20·83	„ „
Sucrose	—	36·75	„ „
Total sugars	—	59·51	„ „
Brix	—	68·60	„ „
Glucose	—	5·33	„ „
Sucrose	—	59·39	„ „
Total sugars	—	61·54	„ „

A very large preponderance of the total ethers in rum is acetic ether, but as this adds little or no flavour, the real aroma of rum must be due to the other ethers such as butyric and those of higher molecular weight.

Acetic acid forms by far the greater proportion of the volatile acids produced in the fermenting houses. It is formed in the souring of cane juice and skimmings, and is produced very quickly when a weak alcoholic liquor is exposed to the air. The oxidation of alcohol to acetic acid is brought about by a class of bacteria which are very abundant everywhere. The manufacturer of flavoured rum makes acetic acid by fermenting rum cane juice and then pumping this liquor on to cane trash. So far this method is correct, but I do not think the generality of distillers fully appreciate the importance of the free access of air in this part of his process. The acetic ferment requires oxygen.

Acetic acid is produced by other classes of bacteria, and there is generally enough of it in still-houses.

Butyric and higher acids.—Volatile fatty acids are produced when organic substances putrefy. Butyric and the higher acids are thus produced by the action of a considerable number of different bacteria, especially a group to which the name of *Proteus* has been given.

I have found organisms of this class in most of the distillery materials which I have examined, and especially from the 'muck hole' of estates making flavoured rum. There is little doubt that these microbes contribute their quota of organic acids, but the chief agents in producing the desired flavour are *Bacillus butyricus*, *B. amylobacter*, and other allied forms.

The method, evolved by experience, of preparing what is called 'flavour' on estates making German rum, is a crude attempt to foster these microbes. Members belonging to this group and their allies are among the most common organisms in nature. They are especially plentiful in the soil. They exist in two states—the vegetative and the spore. The vegetative is a long rod of variable length. The spore develops within the rod and ultimately escapes by bursting the cell wall. If conditions are favourable, the spore germinates and becomes a rod. Under unfavourable conditions it remains dormant, but it is particulary tolerant of adversity, and can survive for a long time, although placed in surroundings where it cannot exert its physiological functions. Hence the reason why, although this class of organism is so prevalent in distillery washes and other materials, its products are not so plentiful. As typical of the class I have referred to, I have isolated *Bacillus butyricus* from distillery materials, and made a careful study of the conditions under which it thrives and performs it physiological functions. *Bacillus butyricus* is an anaerobic organism, that is, it will not develop unless it is grown out of contact with oxygen. The composition of the medium in which it is placed is of importance. In pure cane juice its action is extremely sluggish. In a solution of glucose (invert sugar), to which some albuminous matter has been added, it thrives luxuriantly, and in forty-eight hours after inoculation sets up a strong fermentation. I have found that a medium composed of cane juice and the watery extract of yeast cells is very suitable. This medium closely corresponds to dunder with a little cane juice or molasses added. The temperature at which it grows best is about 35°C. but it thrives very well at the ordinary room temperatures (about 26°C.).

Under these conditions this organism produces butyric acid along with small quantities of other volatile fatty acids such as propionic and acetic. The amount of acid, however, is small, not more than from 0·3 to 0·4 per cent., unless some substance such as calcium carbonate be added to neutralize the acid as it is produced.

Besides the particular organism described, there are others resembling it in its growth and products, some of which develop in contact with air, while others like the Butyricus described, require that oxygen be rigidly excluded.

The point of importance to the distiller is that these organisms ferment sugars converting them into acids, and if the acids be distilled along with alcohol under suitable conditions, aromatic ethers will be produced.

The exclusion of air presents a difficulty not easily surmounted in practical operations on a large scale, but in materials such as one finds in rum distilleries, where the number and varieties of organisms are legion, and the predominating members are aerobic (i.e., require the presence of air), the chances are that those which require oxygen will rapidly develop as long as there is oxygen available, and will thrive best at or near the surface of the medium in which they are, while those of the anaerobic type will find suitable conditions towards the bottom. This I believe is what actually

takes place in distilleries where flavoured rum is made. I have successfully grown mixed cultures of aerobic and anaerobic organisms in this way in the laboratory.

The high-flavoured rum distiller has found by experience that he must supply albuminous matter before he obtains a flavour. This, for the most part, is got from the thick sediment which settles from the dunder and the sludge from the fermenting vats. This sludge is for the most part yeast cells which provide a nutritious medium for bacteria.

Besides the volatile acids described there is always a large proportion of non-volatile acids. Lactic acid is produced from carbohydrates by means of what is known as the lactic ferment. This organism is ubiquitous, and distillery conditions being favourable, its products are plentiful. Being non-volatile it remains in the dunder, and here it is useful in preventing the volatilization of basic substances produced by the bacteria and which would be injurious to the rum.

It is unnecessary to say that the chief organisms concerned in the manufacture of rum are yeasts. While in other branches of the spirit industry, yeasts are almost the only organisms permitted in the wash, it is very different in the case of Jamaica rum. Nature being left with a fairly free hand, it is truly a fight for the survival of the fittest, and the bacteria generally win in the end. So much so is this the case in flavoured washes that I have not been able to isolate yeasts from dead liquors, the yeasts having been entirely swamped by bacteria. The yeasts generally found belong to what are known as wild varieties, and are obtained from the rind of the cane. The species known as schizosaccharomycetes is prevalent in Jamaica. It is easily distinguished from other forms by its microscopic appearance. It forms long, rod-shaped cells resembling more a huge bacterium than a yeast. Its mode of reproduction is distinct from other species. Instead of forming buds it divides into two, forming two individuals which increase in size and again divide into two.

I have found the distribution of this yeast to be general throughout the island, but it is particularly plentiful on north-side estates. In distilleries making high-flavoured rum it is almost the only yeast present in the wash. On other estates it exists in about equal numbers to the oval forms.

On one estate where the development of the yeasts was made a special study, when the distillery started at the commencement of crop, oval forms, which abound on the cane rind, were the only forms which could be detected. After a few cisterns had been set up, the rod forms took possession of the wash. From these and other observations I conclude that the schizosaccharomycetes are less susceptible than the saccharomycetes to acid, and hence find very acid washes such as are used on the northside estates suitable media for their development.

Of other constituents of rum 'higher alcohols' are produced in small amounts by an organism which is extremely abundant in washes—*Bacillus mesentericus* or the potato bacillus. The particular alcohol produced is butyl alcohol

which I believe to be the predominant higher alcohol in Jamaica rum. *Bacillus mesentericus* grown in a wash fermented by yeast gives a pleasant nutty flavour to the dead liquor.

Higher alcohols, furfurol, and aldehydes, although present, are in such minute traces that they cannot have much influence on the flavour. They may, however, contribute in a slight degree to what is indefinitely referred to as 'body.'

There cannot be any doubt but much of the valued qualities of Jamaica rum are due to its high compound ether content, and if these ethers be in the proper proportions, the greater the amount, the more valuable is the rum.

The experiment made on an estate when the price of the rum was raised from 3*s.* 6*d.* to 7*s.* 6*d.* per gallon by simply increasing the ethers, together with the analysis of rums already given, affords conclusive proof of the statement.

It follows, then, that the characteristics of Jamaica rum are derived from saccharine liquors rich in albuminous matter fermented by yeasts and bacteria. Granting that the main difference between high-flavoured rum. and 'common clean' rum is in ether content, the process of manufacture is accountable for this difference, inasmuch as the general bacterial action is greatly increased and special bacteria are developed which produce acids, which on combining with the alcohol form aromatic ethers.

The question of practical importance is—Can the fermentation be scientifically controlled so as to produce flavoured rum? At the present stage of our investigations a conclusive answer cannot be given.

Organisms grown in cultures often give very different products from those produced when they are cultivated in a pure state. There may be either an interaction taking place between their fermentation products, or there may be altogether new products formed. This function of mixed cultures must not be overlooked in any attempt to reproduce a particular flavour by means of pure cultures. It is, indeed, almost certain that particular flavoured rums, as now made, can only be approximately similated by pure cultures.

Hitherto, the distiller has been very much in the dark as to what are the agents at work in the production of flavoured rums. A more accurate knowledge of what constitutes the flavour and how it is produced should minimize the risks of failure which have always been a very serious drawback to the industry.

With flavoured rum, and to a less extent with 'common clean' rum, the methods of manufacture are wasteful of material. This must necessarily be so in order to produce a superior article, and should form one of the strongest arguments why inferior rum made by a less expensive process should be debarred from being sold as Jamaica rum. High gravities, with incomplete attenuation and slow fermentation, with consequent loss of spirit by evaporation, are bound to be uneconomical, but although a certain amount of material must

be sacrificed in order to obtain quality, generally speaking, there is much more waste in distilleries in Jamaica than is necessary. A better control should be exercised, and some sort of balance should be struck between the amount of sugar given to the distillery and the amount of rum produced.

The usual method of checking gallons of rum against tons of sugar is very misleading, and it is worthless as a check. It may happen, and, I fear, too often does happen, that the recovery of sugar from the juice is bad. I have found planters who checked their rum in this way jubilant at the yield they were obtaining from their distilleries, but oblivious of the fact that the molasses supplied from the boiling house contained over 70 per cent. of sugar—10 per cent. more than they should contain.

There is a popular belief in Jamaica that good rum cannot be made on estates with modern sugar machinery. I have not found any evidence to support this belief. I can well understand that it would be difficult to make a superior rum where the amount of materials was too large for the capacity of the distillery. A slow fermentation is essential in order that the bacterial ferments may have time to act. In a rapid fermentation, yeasts swamp the bacteria, and hence the fermentation products of the bacteria are wanting. Given, however, the same conditions in the distillery, I cannot see that the boiling-house plant has anything to do with the quality of rum. Reboiling molasses will lessen the amount of sugar to be fermented and so decrease the quantity of rum, but it cannot affect its quality.

When it becomes fully recognized from what source Jamaica rum derives its characteristics (and I think that has been fairly well established), the planter will be in a much better position to decide on what lines he is to improve his process. He should be able to judge how far he can economize on his materials without sacrificing quality.

The haphazard rule-of-thumb process should give place to a standardized method. A system of complete scientific control involving pure culture methods is impracticable, but an empirical formula based on scientific principles, after the manner used by British distillers, should be applied to the manufacture of rum, and would do much to ensure uniformity of quality with the minimum waste of materials.

IMPROVEMENT OF COTTON BY SEED SELECTION.

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Cotton seed selection is now becoming a subject of great importance in almost every cotton-growing country of the world. Everywhere it is being recognized that the cotton plant is very sensitive and responds to careful cultivation, as well as to neglected treatment, in a most remarkable manner. In the hands of a careful and intelligent planter it has been seen to improve in yield and quality within the space of two or three years; while with careless treatment the good qualities, which have taken years to develop, have been destroyed in a single season.

The United States has taken the lead in the direction of seed selection. From the time that the Sea Island cotton was introduced into that country more than 100 years ago, there have been planters who have had their eyes open to discover any plant with any good character more emphasized than the rest of the plants in their fields. In the first place, by selecting the earliest ripened plants, they were able to produce a plant which occupied a shorter period between the sowing of the seed and the ripening of the crop. By selecting seed from the plants which produce the longest staple, they have been able to develop plants producing a staple $2\frac{1}{4}$ inches in length. Similar results have been obtained by selecting the finest, the silkiest, the most productive, and the healthiest plants. In some cases, as the result of a high degree of specialization, cotton lint has been produced which has sold for as much as 50c. per lb. Such results are not confined to Sea Island cotton; most satisfactory results have also been obtained in both quality and productiveness with the Upland varieties. Many of the long-staple Uplands, which are now being so extensively grown, have been produced by seed selection. Disease-resisting varieties have also been produced by selecting the seed from healthy plants from fields where the majority were diseased. The Rivers' variety of Sea Island, which is resistant to the wilt disease (see *West Indian Bulletin*, Vol. IV, p. 203), is an example of this.

It is only recently that much importance has been attached to seed selection in countries other than America. In Africa, Egypt, and India the general custom has been to purchase seed from a ginnery without knowing anything of its origin. But to-day the importance of seed selection in some form or other is being strongly advocated by all agricultural departments. It has been taken up in the West Indies, in Egypt, and in Africa, and now on a very extensive scale in India. Everywhere the importance of seed selection is becoming more and more realized, and it is expected that in the near future interesting results will be recorded from most of the cotton-producing countries.

As is to be expected, the methods adopted vary considerably. But whatever method is adopted, the selection is carried on with a particular object in view, and the means of attaining that object have to be modified according to the end desired.

The simplest method, however, is to obtain seed grown on an estate which realizes the highest price for its crop. Results tend to show that, unless special methods of selection are adopted, even on the best estates, the value of the seed depreciates rapidly. In the same field there can usually be found some plants producing long, others short staple; some fine lint, others coarse; some produce lint with a silky lustre, while others produce lint with practically no lustre at all; others, again, produce a strong fibre, while there are still others which produce an exceptionally weak fibre. In the same way the productiveness of the plants varies considerably.

If each plant passes on its characters to its offspring, it can be seen from the above that, unless some method of seed selection other than simply selecting the best estate is adopted, there will be a gradual tendency for each crop to become more and more irregular in all its qualities. This irregularity, as is well known, considerably reduces the value of the crop.

One simple method, which has been adopted by certain planters, is to send an intelligent man round the field with a number of pickers; he examines the lint from all good-shaped, healthy, prolific plants, and whenever he finds one with lint which appears to him to be of good length, and, as far as he can judge, is fine, silky, and strong, he directs the pickers to pick all the seed-cotton from that plant. He passes through the field in this way, and after a little experience, a considerable amount of seed-cotton can be collected in a comparatively short time. The seed from this seed-cotton is then used for planting the general crop. By this method all really objectionable seed is got rid of. The examination of the seed-cotton in the field, however, is not of such value as the careful examination in the house.

Some of the best work on seed selection that has been done is to be found in the Sea Island cotton districts of the Southern States. A detailed account of the methods adopted there has already been published in the *West Indian Bulletin* (Vol. IV, p. 208). The principles of this selection are (1) to select a number of the best plants in the field, and (2) to select the seed from the best samples of seed-cotton taken from those plants selected in the field. The seed from these samples is then sown in special plots to multiply it sufficiently to plant all the general crop. Each year the best plants are selected from these special plots to plant other special plots the following year.

Many of the varieties have arisen by the selection of single plants which exhibited certain characters in a very pronounced manner. The seed from such plants, being kept by itself, was sown in special plots to increase it sufficiently for distribution. There has been, no doubt, a very large number of plants selected in this way from time to time, many of which have

been unable to pass on to their offspring the special characters for which they were selected. Any special character which has suddenly arisen is not invariably passed on by the plant to its offspring. In a great many cases the plant reverts at once to the ordinary ancestral characters. It is only by growing the seed that it is possible to learn whether or not the distinguishing character can be transmitted to the offspring.

The improvement of cotton by the production of hybrids is another very interesting and important line of work. In the United States many important varieties have been produced by this method, for example, some of the long-staple Uplands. In India, hybridization is being taken up on a very extensive scale. The Caravonica cotton, about which we hear so much at present, is a hybrid. Hybridization, however, without selection is not of so much value. The introduction of what is generally spoken of in animal breeding as 'new blood' puts new energy into the offspring, making it possible for them to emphasize any particular character towards which they may have an inclination. Hybridization emphasizes the good qualities in some of the offspring as well as the bad qualities in others. In some cases the best qualities of the two parents may be combined; in other cases, the worst qualities. It is not sufficient to be satisfied with examining the general crop taken from the offspring of the same parents, but each plant produced from the seeds of any hybrid should be examined, and the seed from the best only should be propagated for distribution. Cotton being practically self-fertilized, there is a great possibility of obtaining results somewhat similar to those worked out by Mendel for peas. Hybridization is a very slow process, and it will take three or four years before the stability of any plant can be recognized.

INFLUENCE OF CHANGE OF ENVIRONMENT.

It is of special interest to note that in almost every sample of seed-cotton examined, no matter what the general quality of the sample may be, there are indications that some of the plants are bearing lint of a much superior quality to the general sample, as well as others bearing lint of a much inferior quality.

This difference in the quality of the lint produced is not at all surprising. Sea Island cotton has been re-introduced into the West Indies from the United States, where it had been grown for more than 100 years, and where it was thoroughly acclimatized. When the seed is brought to the West Indies, it is brought to a place where the conditions are entirely different. The temperature, the rainfall, the soil, the alternate crops, the methods of cultivation, and other conditions all being different from what obtain in the States, the effect of their combined influences on the plants is necessarily different from the effect of the influences of these various features there. The individuality of the plants here asserts itself, and each plant responds to these influences according to the character of its internal mechanism. From the samples examined it is evident that there are certain plants which find the conditions very unfavourable; there are others which respond fairly satisfac-

torily, while in others, again, the response has been entirely satisfactory, the soil, rainfall, temperature, etc., appearing to be exactly suited to the production of a cotton approaching our ideal. These variations in the way the plants respond to their environment present excellent opportunity for good work to be done by any intelligent planter who is willing to take an interest in this direction.

Again, the conditions which the plant finds in the various West India Islands are very different, and not only are differences found between one island and another, but also between one part of one island and other parts of the same island. As a result of these differences we should expect the plants to vary in their response. This is exactly what occurs. The cotton grown in Barbados is very different from that grown in St. Vincent, and differences also occur between cotton grown in Antigua, Nevis, St. Kitt's, and Montserrat. The cotton grown in the various parts of the same island also differs considerably. This is very well marked in the case of cotton grown on the windward and on the leeward sides of Montserrat.

ADVISABILITY OF SEED SELECTION IN THE WEST INDIES.

In view of the fact that, as a result of the change of environment different plants are responding to the changed conditions in various ways, thus producing a mixed crop, it is advisable to adopt a method of selection. If the seed from a crop which is mixed is sown, the result most likely to be obtained is a more pronounced mixture than the original crop. Mixed cotton in the factory is disastrous. One of the most important things that the spinner notes in buying cotton is uniformity; uniformity in colour, length, fineness, and silkiness; and seeing that West Indian cotton is inclined to be irregular in the characters named, it is essential that steps should be taken to establish uniformity.

Again, in different islands, and in different districts of the same island, equal results are not obtained with the same variety. It is, however, necessary to remember that in each island, and in the several districts of each island, there are plants which are responding satisfactorily to the influences of their environment. The selection of these plants is of immense importance, for, by their selection and careful propagation, it will probably be possible to obtain excellent returns from districts which have hitherto been unsatisfactory. Results already obtained point to the fact that cotton is similar to sugar-cane in this respect, that certain varieties give much better results in certain districts than in others. By careful selection it is also possible to improve the good qualities already being produced. This feature is of great importance, for every slight improvement considerably increases the value of the crop. An increase in the length of the staple would make any crop much more desirable for the finer grades of spinning, and for an increase of lustre and strength the spinner is willing to pay a much higher price. It ought to be the ambition of every planter not only to maintain the various qualities of his crop, but also to improve them in every possible way.

To increase the yield is also a point not to be overlooked. The difference exhibited by the various plants in the same field in this respect is most remarkable. Some plants will produce four or five times as much seed-cotton as others, and if this character of productiveness be passed on to the offspring, and there is every possibility of its being passed on, then the difference between the crop grown from the seed taken from heavy-bearing plants and very light-bearing plants must be considerable.

Those who have been brought up with this variety of cotton in the Sea Islands tell us that, unless careful seed selection is practised every year, the quality of the crop rapidly deteriorates. In fact, amongst these people, it is recognized that Sea Island cotton planting and seed selection are inseparable.

Should selection be discontinued for only a short time, this neglect is at once reflected in the quality of the lint.

Before commencing selection, the planter should know exactly what he wishes to produce. What the spinner most desires must be carefully studied, and then the planter must settle on some scheme which will give the desired lint as well as a sufficient return to make it worth his while to put his fields in cotton.

Planters must remember that it is much cheaper to the spinner to pay a good price for really fine cotton than it is to pay a medium price for an article of poorer quality. What the spinner is desirous of obtaining, and what he is willing to pay a good price for, is a long, fine, strong, uniform, clean cotton with a bright lustre, and these characters, coupled with yield and freedom from disease, supply us with ample material for building up the ideal plant which it is our object to produce.

SEED SELECTION IN BARBADOS, 1905-6.

In the beginning of December 1905, at a conference at which the Imperial Commissioner and officers of the Imperial Department of Agriculture met to discuss the question of seed selection for the next planting season, it was decided to adopt a system based, generally, upon the lines laid down by Mr. Herbert J. Webber, of the U.S. Department of Agriculture, and described in the *West Indian Bulletin* (Vol. IV, pp. 208-14).

It was then arranged that the different officers should be responsible for the selection of plants in the field on different estates. The plants, after being selected, were to be marked with red cloth, and a numbered metal label was to be attached to each. It has also been found very convenient to fix a tall stake in the ground by the side of the plant so as to enable it to be found without difficulty. The seed-cotton produced by these selected plants was to be carefully picked by one picker and placed in separate bags, each bag being numbered, the number corresponding with that already attached to the plant.

It was decided to ask the proprietor or manager on certain estates to co-operate fully with the Department in this matter, and to do all they could to carry out the arrangements entered into between themselves and the officers in charge of the selection.

When the seed-cotton was all picked, the several bags were to be forwarded to the Head Office of the Department where the characters of the cotton could be fully worked out. The seed from plants which gave the best general results was to be used next season for planting selection plots.

The above scheme has now been worked out, and the seed from the best plants is ready for distribution to the various estates upon which it has been grown.

The following are the estates at which these seed selection experiments have been carried out: Rock Dundo and Clapham (St. Michael), Coverley (Christ Church), Dodds, Stirling, and Mangrove (St. Philip), and Stepney (St. George). To prevent any confusion taking place when the samples of seed-cotton were received at this office from the various estates, special numbers were allotted to each estate as follows:—

Coverley	starting	at 1
Rock Dundo	,,	,, 200
Stirling	,,	,, 300
Clapham	,,	,, 400
Dodds	,,	,, 406
Stepney	,,	,, 500
Mangrove	,,	,, 600

In order that the best results may be obtained, it is necessary that selection should be carried on both in the field and in the house. In the field the general characters of the plant are particularly considered: while in the house, the good qualities or otherwise of the seed-cotton are worked out.

FIELD SELECTION.

At the different estates, the following officers were responsible for the selection of the plants in the field:— Mr. J. R. Bovell for the selection at Rock Dundo, Mr. H. A. Ballou for Stirling, Mr. F. A. Stockdale for Clapham and Dodds, and the writer for Coverley, Mangrove, and Stepney.

In the field the healthiest, most vigorous, and best-shaped plants were selected. It is recommended that seed selection should not be commenced in the field until the first bolls begin to open, for then the quality of the lint can be roughly determined. Also, there is always a tendency for a large number of young bolls to fall from the plants just as the first cotton is beginning to mature; hence, if seed selection is not commenced until some of the seed-cotton is ripening, there will be a better chance of getting a more correct estimate of the prolificness of the plant. Again, when the cotton has begun to ripen, many of the older leaves are thrown off; the plants thus become to a certain extent bare, and show up the most prolific ones much more readily.

Plants selected in the field are to be free from disease. It is better that there should be as few large branches from the bottom of the primary stalk as possible. These, when present, are constantly broken off by the weeders and pickers, and the bruised places are favourable to the passage into the plant of such pests as the red maggot. A tall plant is not to be encouraged. These usually give a much lower proportion of seed-cotton than plants of medium height: hence it is not advisable to select plants higher than 5 feet 6 inches. The bolls should be of good size, and as many as possible on the individual branches. The distribution of the bolls should also be general. In the field the seed-cotton can be roughly examined. The fibres should be long, and the seeds neither covered with, nor entirely free from fuzz: it is advisable that they should be tipped with fuzz at one or both ends.

As the plants are selected, it will be a saving of time and trouble to the pickers afterwards if they are numbered regularly, rather than any number being attached to any plant in any part of the field.

The number of plants selected on the different estates was:—

Rock Dundo	...	100 plants
Stirling	...	15 ,,
Clapham	...	6 ,,
Dodds ...	...	17 ,,
Coverley	. .	8 ,,
Mangrove	...	25 ,,
Stepney	..	93 ,,

The field characters for the plants finally selected for both field characters and the quality of the seed-cotton are:—

No. 2. Habit, slightly inclined; 3 feet high: one small basal branch, bolls large and pointed; number of bolls, 89; maximum number of bolls per branch, 6: distribution of bolls, general: slightly infected with mildew.

No. 4. Habit, slightly inclined: height, 5 feet: no basal branches: bolls of medium size and pointed; number of bolls, 51; maximum number of bolls per branch, 5: distribution of bolls, general; slightly infected with mildew.

No. 6. Habit, erect; height, 5 feet; no basal branches; bolls, medium size with medium pointed end; number of bolls, 66; maximum number of bolls to branch, 6: distribution of bolls, general; the oldest leaves infected with mildew.

No. 210. No field notes made.

No. 233. No field notes made.

No. 300. Habit, erect: height, 5½ feet: three medium basal branches, one bearing ten bolls; pod, long, slender and pointed: number of bolls, 86; distribution, most of the bolls on the lower part of the plant.

No. 301. Habit, straight, erect; height, 5 feet; four small basal laterals well podded: stem medium and compact: bolls medium sized, slender and well pointed: number of bolls, 93: distribution of bolls, general.

No. 303. Habit, bent with wind: height, 5 feet: several small basal laterals; bolls of medium size, slender and pointed: number of bolls, 83; distribution of bolls, general, some laterals with seven; healthy.

No. 401. Habit, erect: medially developed: stalk inclined to be thick; bolls medium size; number of bolls, 80: resistance to disease, medium.

No. 416. Habit, fair, one basal lateral broken, showing red maggot; stalk slender; one basal branch with few bolls on it; bolls good size; number of bolls, 65.

No. 422. Habit, erect, one basal lateral broken off: stalk medium; bolls medium size; number of bolls, 72: resistance to disease good; position, in the outside row.

No. 518. Habit, erect; height, 4 feet: one good basal lateral: internodes, short: distribution of bolls, general: healthy.

No. 569. Habit, erect: height, 5 feet, no basal laterals: internodes, medium: maximum number of bolls on single branch, 8; distribution of bolls, general; healthy.

No. 600. Habit, slightly inclined; height, 4 feet: no basal laterals: bolls medium size, pointed: number of bolls, 53; maximum number of bolls on branch, 5; distribution of bolls, general; slightly infected with mildew.

It is important to note that on some estates very few plants can be found, when nearing maturity, which are not slightly infected with mildew.

At the end of the picking season, the bags of seed-cotton were all sent to the Head Office of the Imperial Department of Agriculture where they were further examined, and the best samples selected.

SELECTION IN THE LABORATORY.

In selecting the best samples of seed-cotton taken from the plants selected in the field, a process of elimination was adopted. The first examination was only cursory; but, by this rapid examination, a large number of samples was discarded. Seed-cotton with clean black seeds, or with short or coarse lint, was cast on one side without further examination.

For a more careful examination, sixteen plants were selected from Rock Dundo; seven from Stirling; one from Clapham; eight from Dodds; eight from Coverley; three from Mangrove; and ten from Stepney.

The examination of the seed-cotton was carried out according to the method indicated in the *Agricultural News* (Vol. V, p. 38) certain modifications being introduced. The same scheme may be found useful for all places, but before fixing upon any definite limit for any particular character, a number of samples should be examined to obtain an idea of the general quality of the product. This scheme simplifies matters considerably, and makes it possible to determine the best samples out of a large number in a comparatively short time.

After the cursory examination mentioned above, the samples selected from the whole collection were first examined as regards length. If satisfactory in this respect they were examined further. At each step the unsatisfactory samples were eliminated, only those which proved to be satisfactory being further examined.

The characters for which the samples were examined are: (1) Length of staple and uniformity of length; (2) weight of seed-cotton per plant; (3) weight of seed-cotton per boll; (4) proportion of weak fibre; (5) proportion of lint to seed; (6) proportion of lint per plant; (7) diameter of fibres; and (8) general appearance, including fineness and silkiness.

Out of fifty-five samples which passed satisfactorily through the primary examination, twenty-eight were found to be too short. It was intended to consider 50 mm. as the minimum limit: but in practice it was found impossible to fix this limit, as the best plant on each estate was to be selected, and where none measured 50 mm., the longest sample had to selected. In this way Nos. 4, 5, 401, 518, 558, 569, and 619 were selected for further examination, though none of them measured 50 mm., although approaching it closely.

The weight of seed-cotton per plant was next determined, and all samples which did not weigh 100 grammes were discarded. Those plants failing to produce the required weight were Nos. 5, 246, 283, 406, 558, 602, and 619.

The next character examined was the proportion of weak fibre, 30 per cent. being fixed as the maximum limit. Samples 2 and 422, however, just exceeded this limit, but it was considered advisable not to discard them. The proportion of weak fibre is remarkably low in most of the samples, only four being discarded, viz., Nos. 313, 410, 417, and 420.

The proportion of lint to seed was next determined, no definite limit was fixed, and No. 309, only, was discarded. The proportion of lint to seed in this instance was only 23·7 per cent.

The general appearance is very important. The samples which have given satisfaction in the characters already examined are in all cases both fine and silky.

The weight of seed-cotton per boll is an important feature. Some planters might wish to develop a large boll; this will be much easier to pick the cotton from than a small one, and if each boll can be increased in size it is very probable that the size of the general crop will be increased. In our experiments we have determined the weight of seed-cotton per boll, but this was done in order to have on record as full an account of the original plants as possible.

The size of the seed is also likely to be of interest. Large seeds are now generally recognized to produce more vigorous plants than small seeds. In cotton planting, however, there is another feature to take into consideration, namely, the proportion of lint to seed. The larger the seed, the smaller the proportion of lint to seed; and if the seed is materially reduced, the fibre-producing area will also be reduced. It will be of interest to see the results from plants grown in one instance

from small seeds, and in another from large seeds. In our experiments, they differ considerably, the number in 50 grammes varying between 381 and 486 seeds.

The diameter of the fibres is also important. The cotton with the smallest diameter is most suitable for spinning fine grades. Regularity in diameter of the fibres is also desirable, some samples being much more regular in this respect than others. No special selection has been done with this character. On examination, the samples selected were found very satisfactory.

Out of the 264 plants first selected in the field, only fourteen have given satisfaction in all the characters examined, viz., at Coverley, three; Rock Dundo, two; Stirling, three; Clapham, one; Dodds, two; Stepney, two; and Mangrove, one; their numbers being 2, 4, 6, 210, 233, 300, 301, 303, 401, 416, 422, 518, 569, and 600.

The number of seeds produced per plant varies between 700 and 1,600. The seed from each plant is to be sown in a separate plot which will be numbered with the number of the plant from which the seed was obtained. It is recommended that only one seed be planted to the hole, that the rows be 6 feet apart, and the plants in the rows not less than 2 feet apart.

The position of the plot should be such as will give as little chance as possible for cross-fertilization with other unselected plants.

The results of the selection and examination of the seed-cotton described above are given in tabular form at the end of this paper, so as to show at a glance the characters of every sample and the position in the examination where any sample was discarded.

The following methods have proved to be useful in determining the various qualities :—

(1) *Length of staple.*—To determine the length of staple, a number of seeds should be selected from the sample of seed-cotton, the number of seeds depending on the size of the sample. When examining the seed-cotton from the individually selected plants, it is convenient to take about ten seeds from different parts of the sample; the length of the lint on these is measured, the minimum and maximum noted, and the average determined. The length of a large bunch of fibres must not be measured when ascertaining the length of the staple; more reliable results are obtained by measuring the length of a few carefully arranged fibres.

(2) *Proportion of lint to seed.*—When much of this work is to be done, it is convenient to remove the lint from the seed by means of a hand gin. To remove it by the hand is very laborious work, and if it is done with an ordinary gin in the factory, it not only wastes the time of the factory hands, but there is always a difficulty in obtaining all the seed.

After the separation has been made, the proportion of lint to seed is determined by weight.

It is questionable, however, if so very much importance ought to be attached to the proportion of lint to seed. The variation is, no doubt, due to more than one cause, the most obvious being the varying quantity of lint on the seed. Another factor might here be put forward, viz., a larger weight of seed. The smaller proportion of lint in this case is only apparent; it is therefore desirable that the quantity of lint per plant should be considered, as well as the quantity of lint on, say, 100 seeds. A general result obtained in the West Indies is a smaller proportion of lint to seed picked towards the beginning of the crop, but later the normal condition is obtained. The probable reason for this is that towards the beginning of the crop there is a greater supply of water, and at this season more moisture is stored in the seed than later. This would make the seed heavier and the proportion of lint to seed less.

(3) *Proportion of weak fibres.*—On each seed there are two sets of fibres, viz., strong and weak. The weak fibres have been arrested in development and possess walls which are extremely thin and transparent. The strength of the lint is practically determined by the proportion of these weak fibres present. The breaking strain of the two sets is as 3 to 1, and this fact is the one on which the principle of separation is based. After the process of ginning, the strong and weak fibres are so mixed together that it is impossible to determine the proportion in which each is present; but while attached to the seed it is possible to separate them by drawing through them a weaver's fine steel comb. The teeth of this comb are fairly close together, and as they pass through the fibres, they offer a certain amount of resistance, and if carefully done, the resistance is sufficient to break the weak fibres from the seed, but not sufficient to break away the strong fibres.

The fibres attached to the seed are first carefully straightened out by means of the fingers. They are then combed out straight, close to the seed; and then, holding them at this point between forefinger and thumb, the loose ends are combed out straight. When the ends have been straightened, the comb can be drawn through their whole length, and the weak fibres will leave the seed, the strong ones remaining attached. The strong fibres can afterwards be detached from the seed, and the proportion of strong and weak determined by weight.

In order to obtain good results it is best to work out 100 seeds: these should be taken from all parts of the sample.

(5) *Diameter of fibres.*—The diameter of fibres must be ascertained microscopically by means of a graduated eye-piece. This work can be done very rapidly. It is not advisable to measure the weak fibres, these being flat and consequently broader, and besides they constitute a factor which we are trying to eliminate. Five mounts should be made from the sample, and the diameters of twenty fibres measured in each mount.

(6) *Silkiness.*—Up to the present there is no scale for determining the silkiness of any sample, and in any case, it can only be an arbitrary one.

(7) *Fineness.*—Fineness is exhibited by the general appearance, but it is only after a long experience that one can correctly judge the quality of this character. If a rough Peruvian is placed side by side with a sample of ordinary Sea Island, it is seen that the behaviour of the fibres in the two samples is very different. In the Peruvian, the individual fibres stand out from one another; but the fine fibres of the Sea Island samples lie close together. If a series of Sea Island cotton samples be placed together, it can be seen that they differ amongst themselves in this particular, and when a handful is pulled apart, it shows up, in the finer samples, like so many locks of fine silk, while in the coarser samples the fibres all separate more or less from one another.

On account of seed selection being only recently applied to cotton in the West Indies, the details of the selection and examination described above may appear to the West Indian planter to form too elaborate a scheme to be carried out by any one, unless considerable time is devoted to it. It is not our wish to mislead any one by saying that no labour or time is required. To carry out the work well, both are required, and the better the results to be obtained, the more labour and time must be given to it. It is, however, certain that the time and labour spent in cotton seed selection will be fully repaid.

Plant No.	Length of staple.			No. of bolls per plant.	Weight of seed-cotton per plant.	Weight of seed-cotton per boll.	Proportion of weak fibres.	Proportion of lint to seed.	Weight of lint per plant.	No. of seeds in 50 grammes.	Diameter of fibre.	General appearance.		General remarks.
	min.	max.	average.		grms.	grms.	per cent.	per cent.	grms.			Fineness.	Silkiness.	
1	45 mm.	48 mm.	46·6 mm.	—	—	—	—	—	—	—	—	—	—	—
2	46 ,,	54 ,,	53·3 ,,	89	120·16	1·35	32·4	27·4	32·92	448	0·0153 mm.	1	1	fine.
3	44 ,,	48 ,,	45·7 ,,	—	—	—	—	—	—	—	—	—	—	—
4	46 ,,	51 ,,	49·0 ,,	51	101·95	2·00	29·2	28·4	28·94	397	0·0162 ,,	1	1	fine.
5	47 ,,	51 ,,	49·4 ,,	57	95·81	—	—	—	—	—	—	—	—	—
6	48 ,,	54 ,,	50·0 ,,	66	112·22	1·70	29·4	31·0	34·78	428	0·0162 ,,	1	1	fine.
7	47 ,,	51 ,,	48·8 ,,	—	—	—	—	—	—	—	—	—	—	—
8	44 ,,	50 ,,	46·7 ,,	—	—	—	—	—	—	—	—	—	—	—
205	45 ,,	49 ,,	47·0 ,,	—*	—	—	—	—	—	—	—	—	—	—

* No record made of field characters.

Plant No.	Length of staple.			No. of bolls per plant.	Weight of seed-cotton per plant.	Weight of seed-cotton per boll.	Proportion of weak fibres.	Proportion of lint to seed.	Weight of lint per plant.	No. of seeds in 50 grammes.	Diameter of fibre.	General appearance.		General remarks.
	min.	max.	average.		grms.	grms.	per cent.	per cent.	grms.			Fineness.	Silkiness.	
208	46 mm.	51 mm.	48·6 mm.	—*	—	—	—	—	—	—	—	—	—	—
210	48 ,,	53 ,,	50·8 ,,	—*	249·45	—	25·5	28·5	71·1	472	0·0159 mm.	1	1	fine.
215	45 ,,	52 ,,	48·5 ,,	—*	—	—		—	—	—	—	—	—	—
219	43 ,,	50 ,,	46·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
222	43 ,,	54 ,,	49·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
227	45 ,,	53 ,,	49·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
230	46 ,,	52 ,,	48·6 ,,	—*	—	—	—	—	—	—	—	—	—	—
233	48 ,,	53 ,,	51·0 ,,	—*	131·52	—	26·0	30·1	39·58	464	0·0156 ,,	1	1	fine.
240	43 ,,	50 ,,	47·8 ,,	—*	—	—	—	—	—	—	—	—	—	

* No record made of field characters.

Plant No.	Length of staple.			No. of bolls per plant.	Weight of seed-cotton per plant.	Weight of seed-cotton per boll.	Proportion of weak fibres.	Proportion of lint to seed.	Weight of lint per plant.	No. of seeds in 50 grammes.	Diameter of fibre.	General appearance.		General remarks.
	min.	max.	average.		grms.	grms.	per cent.	per cent.	grms.			Fineness.	Silkiness.	
246	48 mm.	53 mm.	50·7 mm.	—*	79·04	—	—	—	—	—	—	—	—	—
261	44 ,,	52 ,,	49·2 ,,	—*	—	—	—	—	—	—	—	—	—	—
263	46 ,,	50 ,,	48·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
279	50 ,,	57 ,,	52·2 ,,	—*	176·40	some of seeds approaching clean black one			—	—	—	—	—	—
282	48 ,,	51 ,,	49·1 ,,	—*	—	—	—	—	—	—	—	—	—	—
283	47 ,,	52 ,,	50·3 ,,	—*	86·50	—	—	—	—	—	—	—	—	—
300	50 ,,	55 ,,	52 ,,	86	166·02	1·93	26	25	41·50	418	0·0148 mm.	1	1	very fine.
301	48 ,,	52 ,,	50 ,,	93	215·74	2·32	26	28	60·41	466	0·0156 ,,	1	1	,, ,,
303	48 ,,	52 ,,	52 ,,	83	225·70	2·72	24	30	67·71	480	0·0145 ,,	1	1	,, ,,

* No record made of field characters.

Plant No.	Length of staple.			No. of bolls per plant.	Weight of seed-cotton per plant.	Weight of seed-cotton per boll.	Proportion of weak fibres.	Proportion of lint to seed.	Weight of lint per plant.	No. of seeds in 50 grammes.	Diameter of fibre.	General appearance.		General remarks.
	min.	max.	average.	†	grms.	grms.	per cent.	per cent.	grms.		grms.	Fineness.	Silkiness.	
305	46 mm.	49 mm.	47·4 mm.	—	—	—	—	—	—	—	—	—		—
309	45 „	53 „	50 „	80	166·97	2·09	25·5	23·17	—	—	—	—		—
313	49 „	55 „	52 „	89	174·00	1·96	42·0	—	—	—	—		—	—
314	46 „	51 „	49 „	—	—	—	—	—	—	—				—
401	48 „	51 „	49·7 „	70 [10]	160·35	2·29	26·4	27·6	44·26	411	0·0158	1	1	fine.
406	52 „	55 „	53·4 „	68 [10]	68·42	—	—	—	—	—	—	—	—	—
410	48 „	55 „	52·2 „	61 [18]	104·85	1·72	37·7	—			—		—	—
411	42 „	52 „	48·1 „				—	—	—		—			
416	48 „	52 „	50·8 „	55 [10]	260·86	4·71	27·8	26·6	69·39	432	0·0147	1	1	very fine, but rather soft

† Small figures in this column indicate the number of bolls picked before selection commenced.

Plant No.	Length of staple.			No. of bolls per plant.	Weight of seed-cotton per plant.	Weight of seed-cotton per boll.	Proportion of weak fibres.	Proportion of lint to seed.	Weight of lint per plant.	No. of seeds in 50 grammes.	Diameter of fibre.	General appearance.		General remarks.
												Fineness.	Silkiness.	
	min.	max.	average.	†	grms.	grms.	per cent.	per cent.	grms.		grms.			
417	52 mm.	56 mm.	54·0 mm.	75+2	133·14	1·77	32·5	—	—	—	—	—	—	—
418	44 ,,	54 ,,	49·4 ,,	—	—	—	—	—	—	—	—	—	—	—
420	48 ,,	54 ,,	51·6 ,,	78	140·5	1·80	33·3	—	—	—	—	—		—
422	47 ,,	53 ,,	50·9 ,,	68+4	258·7	2·64	31·1	24·7	63·90	484	0·0153	1	1	very fine, but rather soft.
502	42 ,,	51 ,,	47·5 ,,	—*	—	—	—	—		—	—	—	—	—
518	42 ,,	53 ,,	49·5 ,,	—*	128·6		25·0	26·4	33·95	405	0·0163	1	1	fine.
527	43 ,,	50 ,,	47·8 ,,	—*	—	—	—	—	—	—	—	—	—	—
536	45 ,,	50 ,,	47·6 ,,	—*	—	—	—	—	—	—	—	—	—	—
538	41 ,,	51 ,,	47·1 ,,	—*	—	—	—	—	—	—	—	—	—	—

* Number of bolls not recorded. + Small figures in this column indicate the number of bolls picked before selection commenced.

Plant No.	Length of staple.			No of bolls per plant.	Weight of seed-cotton per plant.	Weight of seed-cotton per boll.	Proportion of weak fibres.	Proportion of lint to seed.	Weight of lint per plant.	No. of seeds in 50 grammes.	Diameter of fibre.	General appearance.		General remarks.
	min.	max.	average.		grms.	grms.	per cent.	per cent.	grms.		grms.	Fineness.	Silkiness.	
541	45 mm.	50 mm.	48·2 mm.	—*	—	—	—	—	—	—	—	—	—	—
558	48 ,,	51 ,,	49·3 ,,	—*	61·9	—	—	—	—	—	—	—	—	—
562	44 ,,	51 ,,	48·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
568	45 ,,	51 ,,	48·1 ,,	—*	—	—	—	—	—	—	—	—	—	—
569	48 ,,	52 ,,	49·5 ,,	—*	163·2	—	28·4	27·7	45·21	381	0·0162	1	1	fine.
586	43 ,,	50 ,,	48·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
588	43 ,,	50 ,,	47·7 ,,	—*	—	—	—	—	—	—	—	—	—	—
600	50 ,,	55 ,,	52·3 ,,	53	132·38	2·49	26·5	31·1	41·17	486	0·0156	1	1	fine.
602	53 ,,	58 ,,	55·1 ,,	59	62·8	—	—	—	—	—	—	—	—	—
619	48 ,,	52 ,,	49·7 ,,	52	90·3	—	—	—	—	—	—	—	—	—

* Number of bolls not recorded.

MANURING COTTON.

'Notes on Egyptian Agriculture,' by Mr. George P. Foaden, B.Sc., published as Bulletin No. 62 of the Bureau of Plant Industry, U. S. Department of Agriculture, contains interesting information in regard to the cultivation of cotton in Egypt. Mr. Foaden discusses the general principles of cotton manuring as follows:—

The question of manures and manuring is assuming greater importance in Egypt than formerly. When the Delta was under a basin system of irrigation and receiving annually the life-giving deposit of the Nile, and when, consequently, the cultivation of a summer crop, such as cotton, was impossible, there was not that need for manure which exists to-day. The introduction of perennial irrigation and the more intensive cultivation, which follows in its train, have, however, brought about a great change, and the idea that the soils of the Nile Valley are inexhaustible is a myth which is being rapidly dispelled. True, in the basin lands of Upper Egypt the ancient conditions still prevail, but this section is in a state of transition; and that system which has been typical of the country for so many thousands of years is now giving place to perennial irrigation and the consequent abolition of the one-crop system in favour of a more intensive culture.

The interdependence of water and manure has already been referred to, and whenever land is artificially irrigated the need for manure at once arises. The two questions of water and manure are really intimately connected, and the supply of one should always be considered with reference to that of the other. Where land is artificially irrigated in Upper Egypt, the demand for manure, as already mentioned, is very great, and even in the basins themselves, when watering by means of wells is practised, manure is employed.

In the Delta the supply of manure is considered especially in its relation to the cotton and corn crops, but at present we shall confine ourselves to the question of cotton. It is generally laid down that from eight to ten working bullocks per 100 acres are required in Egypt, and in addition there are mules for transport, as well as cows, buffalos, etc., kept both for milk purposes and for breeding. If it is assumed that about one-half of the area of each farm is under cotton, so far as work animals themselves are concerned, there are from eight to ten, say, to every 50 acres of cotton, and in addition to this, manure has to be provided for other crops. It is seen, therefore, that in comparison with the conditions prevailing in the cotton-growing states of America there is a much greater quantity of natural fertilizer at the disposal of the cultivators, though, unfortunately, far from sufficient. Earth is in universal use as litter, and the heaps of manure which one sees surrounding every village are evidence of the great value which even small cultivators attach to the fertilizer question.

It is accepted as beyond question by every Egyptian cultivator that cotton requires manuring, and in many cases

the cotton area has been governed by the amount of manure available. Manure and water, in fact, tend to control the area under cotton. At one time it was thought that maximum crops could be raised by ordinary stable manure alone, but during the past five years a great change of opinion has made itself felt. The introduction of chemical fertilizers has not only resulted in increased returns, but has made possible the manuring of a greater area. Instead of applying stable manure, as previously, to a portion of the cotton area and leaving of necessity a part unmanured, it is now accepted that the best practice consists in spreading the stable manure over the whole area and supplementing it by chemical fertilizers.

The question of cotton manuring is not an easy one, where not only has the yield to be considered, but (and especially is this the case in Egypt) also the quality. It is unnecessary to state that as a cotton-growing country Egypt is noted for the quality of its product, and consequently, while endeavouring to obtain the greatest product possible from a given area, the question of quality is one which is ever brought home to the cultivator.

It may be laid down as an axiom that the basis of cotton manuring in Egypt must be organic manures. These must form, as it were, the foundation on which to build up the system of manuring. Unfortunately, in Egypt, as in India, organic matter is at a premium. The absence of wood as fuel necessitates the poorer classes employing every form of organic matter for this purpose, and were it not for the growth of clover it is certain that the soils would speedily become deficient in humus. It is true that by means of chemical manures alone full crops of cotton may be obtained, but in this case, if a cereal crop follows the cotton, the result is not so satisfactory as when the cotton receives stable manure, while the cost of raising the cotton is increased.

Stable manure is almost invariably spread broadcast over the land before the last ploughing is given in the preparation of the land. The amount applied varies from 10 or 15 tons per acre to as much as 30 tons. It is not possible, however, on a farm of any extent to find a sufficient quantity of manure to treat the whole cotton area as liberally as 30 tons or even 20 tons per acre. In fact, it is rarely that large growers can find sufficient manure to apply as much as 15 tons per acre, especially so as a greater portion of the land is now under cotton. It may be assumed, however, that under the ordinary circumstances of successful agriculture 15 tons per acre are employed.

The manure is certainly not covered as deeply as in America, the use of the native plough, after its distribution over the land, resulting in its being buried to a trifling depth only. The irrigation water employed tends to wash the valuable ingredients of the manure down into the soil: furthermore, in Egypt great importance is attached to the feeding of the cotton plant during the early stages of growth, and opinion would rather be opposed to burying the manure as deeply as is prac-

tised in the cotton states of America. It is again laid down as a rule that the manure should be old ; that is, should have been in the heap for some time. The use of fresh stable manure causes rank growth, late maturity, and an inferior fibre.

Though great importance is attached to the use of stable manure, the best results are not, as a rule, obtained when large quantities are used without the application of chemical manures. The basis of the mixture of chemical manures employed is superphosphate. About 400 ℔. per acre of this substance are applied, the quality in common use being that which contains 16 to 18 per cent. of soluble phosphoric acid. It is found that this substance exercises a most beneficial effect on the crop. It checks the tendency to coarse growth, and thus encourages ripening, while it greatly improves the quality of the fibre. It is generally considered that the best results are obtained when this manure is applied previous to the sowing of the crop. The use of basic slag as a substitute for superphosphate has not been attended with satisfactory results, the more soluble forms of phosphoric acid being preferred.

While phosphoric acid is the basis of the mixture of manure employed, it is universally conceded that the application of soluble nitrogenous manures during the early stages of growth is most beneficial. It is found that the cotton plants require pushing when young, and that though there may be theoretically quite sufficient nitrogen in the stable manure applied, it does not act as early as is advisable ; in fact, when large quantities are applied, it causes growth at too late a period, and consequent harm. Some few years since, when the idea gained ground that the question of the manuring of cotton merited more attention than had been given to it in the past, some excellent cultivators, by the addition of large quantities of organic manures, produced cotton of poorer quality than they had grown previously with a less liberal application.

The question whether nitrate of soda or sulphate of ammonia is the more suitable substance to employ as the basis of nitrogenous manuring, or whether a mixture of the two is advisable, has been made the subject of many experiments. There were those who maintained that the former would be almost entirely washed away by the irrigation water employed. The results which have been obtained indicate that when barnyard manure is applied, there is little need for any nitrogenous fertilizers which do not supply nitrogen in the very early stages of growth. When considerable quantities of sulphate of ammonia are applied, there is a tendency to cause excessive growth late in the season, and on account of the failure to ripen there is often a considerable diminution in the yield. On the other hand, when nitrate of soda predominates. the plant receives a supply of nitrogen just when it is wanted at the early stages, and this gives the plant that good start which is so essential in cotton culture. That there is a loss of a part of the nitrogen is probable, but the effects of its application are always most pronounced and profitable. The benefit derived from the part which is not lost is more than sufficient on ordinary soils to pay for its cost.

It is generally considered that in addition to an application of 10 or 15 tons of stable manure it is profitable to employ as much as 150 or 200 ℔. of soluble nitrogenous manure, and two-thirds nitrate of soda and one-third sulphate of ammonia give excellent results. Experiments have clearly proved that better results are obtained when the amount of nitrate of soda predominates than when the greater part consists of sulphate of ammonia, assuming that an organic manure has been applied, which should always be the case when possible.

The employment of cotton seed or cotton-seed meal is out of the question in Egypt, the seed being considered too expensive. It is more costly than in the United States, and practically the whole of it is exported. The economy of the use of cotton seed and cotton-seed meal as such, as sources of nitrogen for the cotton crop, seems to the writer to be very questionable. In passing through the body of an animal comparatively little of the valuable fertilizing ingredients of the meal are retained, but are found in the resulting manure. It seems, therefore, more practical to employ stable manure or green manures as the basis of manuring in Egypt, and to supplement these by the use of such substances as superphosphate, nitrate of soda, and potash manures to supply the deficiency.

Soluble nitrogen gives size to the plant, and, up to a certain point, a larger and more vigorous plant means an increased yield. It is often argued that the production of large plants reduces the yield, and this may be true to a certain extent; but this arises generally from the plant being stimulated too late. Excessive growth is produced by manures containing nitrogen which act too late in the season. This objection is not felt in the case of manures which supply their nitrogen early, but with those which continue to push the plant too late.

The employment of potash manures in Egypt has not, generally speaking, been attended with satisfactory results, except in the case of light soils. The alluvial soils of Egypt are, as a rule, very rich in potash, and, though potash manures may have a beneficial effect on the quality of the fibre, as far as yield is concerned they exercise practically no effect. Sulphate of potash is the substance generally employed.

As a general rule a mixture of 400 ℔. of superphosphate, 125 ℔. of nitrate of soda, 50 ℔. of sulphate of ammonia, and, provided it is thought necessary, about 80 or 90 ℔. of sulphate of potash, gives the best results. This mixture is employed in addition to stable manure. Discretion must be exercised as to the quantity of soluble nitrogenous manures to employ. On many soils, which naturally produce very strong growth, the amounts given may be excessive, but even with the relatively large growth of Egyptian plants there are very few soils where nitrogenous manures may not be used with advantage.

Stable manure contains, on an average, about 0·25 per cent. nitrogen, 0·2 per cent. phosphoric acid, and 1·25 per cent. potash, so that each ton contains about 5½ ℔. of nitrogen, nearly 5 ℔. of phosphoric acid, and about 28 ℔. of potash. If it is assumed that over the cotton area 10 or 15 tons are,

on an average, applied per acre, it is equivalent to at least 55 lb. of nitrogen, 50 lb. of phosphoric acid, and 280 lb. of potash. A great part of these ingredients is derived from the soil itself which was used as litter, and the availability of the various elements must be very low. It is generally thought that, in addition to this, about 30 lb. of nitrogen and 60 lb. of phosphoric acid in available forms are necessary to produce a good crop on land which grows from a bale to a bale and a quarter of cotton per acre. Numerous experiments have shown that these quantities can be applied with advantage to the great bulk of the cotton area.

As already mentioned, the barnyard manure is applied broadcast before the last ploughing, and the phosphoric acid is also generally applied before sowing. The nitrate of soda and the sulphate of ammonia, however, are mixed together and applied after the cotton has received its first watering. The plants, generally speaking, are thinned before this watering, and after the second hoeing has been given the nitrogenous manure, mixed with a little earth, is applied at the base of the plants, hoed in, and the second watering given. This occurs in the month of April, and the effects of the manure are seen almost immediately after the watering. Spells of fresh weather often somewhat retard growth during the early months, and the advantages to be obtained by tiding the plant over this period and keeping it steadily growing are very marked.

It may be of interest to give some of the results of experiments which have been made in Egypt during the past three or four years on the subject of cotton manuring. This question was first systematically investigated by the Khedivial Agricultural Society, and, as the result of experiments which have been conducted on their experimental farms, the matter has assumed great importance, since it is being recognized to a greater extent year by year that by the employment of suitable mixtures of manures profitable increases in yield, as well as an improvement in quality, can be obtained. During the seasons of 1901 and 1902, experiments conducted on somewhat poor land at the Society's farm at Mit el Diba showed that when, in addition to stable manure, a suitable mixture of commercial fertilizers, consisting of 400 lb. of superphosphate, 125 lb. of nitrate of soda, 50 lb. of sulphate of ammonia, and 80 lb. of sulphate of potash, was employed, the yield of seed-cotton was increased from 880 lb. on unmanured land to 1,595 lb. The yield obtained by the use of stable manure alone was 1,135 lb., or 460 lb. less than when commercial fertilizers were employed in conjunction with it. By the use of mineral manures alone, in addition to stable manure, the yield obtained was 1,340 lb. of seed-cotton, whereas an increase of 260 lb., or a total of 1,600 lb. of seed-cotton, was obtained when supplemented by nitrate of soda.

As already mentioned, the use of potash salts is attended with practically no increase in yield on the ordinary alluvial soil of the Delta, though when the soils are light the case may be different. This fact has been brought out in many experiments; though whether the use of these salts exercises any

effect on the length, strength, or fineness of the staple is a matter for further determination.

The influence of the growth of Egyptian clover preceding cotton is most marked on poor land. On the Khedivial Agricultural Society's farm, in the province of Gharbieh, an experiment was conducted during the season of 1902 on land of similar quality. In one case, series of fertilizer trials were conducted on land where the cotton crop had been preceded by wheat, and in the other case by clover. The results obtained in pounds of seed-cotton per acre are given below in a tabulated form :—

EFFECT OF CHEMICAL FERTILIZERS ON COTTON IN EGYPT.

Kind of fertilizer.	After wheat.	After clover.
	℔.	℔.
Without manure	800	880
With stable manure only	1,032	1,135
With superphosphate and potash salts	1,005	1,340
With superphosphate, potash salts, and soluble nitrogenous manure	1,105	1,595

It will be seen that the greatest difference is brought out when a mixture of fertilizers is employed, and is least when the crop is grown without manure. It may be stated conclusively, therefore, that the use of chemical fertilizers, in conjunction with stable manures, exercises a very beneficial effect and gives a profitable return. The proportion of nitrogen employed is greater than seems to be the case usually in the United States, and a dressing of soluble nitrogenous fertilizer can be applied in Egypt with advantage, even though barnyard manure is employed, or when following a crop of clover, except on the very best land. The extent of land which is not benefited is very limited, even in Egypt. It may be that, theoretically speaking, sufficient total nitrogen is found in either of the two (that is, barnyard manure and clover), but they push the plant a little too late in the season and do not enable it to grow so rapidly in the younger stages as is the case under the influence of a more quickly acting source of nitrogen.

The use of soluble nitrogenous manures must not be carried beyond a certain point or there is a great tendency to late maturity. The influence of phosphoric acid in hastening maturity is most marked, and when employed in sufficient quantities in conjunction with soluble nitrogenous manure it checks any tendency of the latter to prolong growth. The use

of phosphoric acid without soluble nitrogen gives an earlier crop, but a diminished yield in comparison with that obtained by a combination of the two. Again, soluble nitrogen without phosphoric acid gives also a diminished yield and a late crop. A mixture of the two gives an increased yield and intermediate conditions as regards ripening. This will be made clear from the following table, showing results obtained in an experiment where these manures were employed, the figures referring to pounds of seed-cotton per acre on poor land :—

EFFECT OF A MIXTURE OF PHOSPHORIC ACID AND SOLUBLE NITROGEN ON COTTON IN EGYPT.

Manuring.	First picking.	Second picking.	Third picking.	Total.
	lb.	lb.	lb.	lb.
Phosphoric acid only ...	835	420	400	1,655
Soluble nitrogen only ...	138	455	900	1,493
Phosphoric acid, together with soluble nitrogen ...	435	935	870	2,240

There can be no doubt that organic manures must form the foundation of the Egyptian system of manuring, but it is rare, unfortunately, that a sufficient supply can be obtained by the farmer, and this is more especially the case in view of the tendency to put an increased area under cotton. In Egypt there is no substitute for barnyard manure in any quantity to fall back upon, though poudrette and similar substances give excellent results when so employed.

As regards quality, samples of soil from experimental areas have been repeatedly submitted to experts, and when a suitable mixture of chemical fertilizers has been employed there has always been an improvement in comparison with the employment of large quantities of barnyard manure only.

SUMMARY.

Summarizing, the following statements may be made :—

(1) The cotton crop is almost invariably manured and responds freely to the application of manures.

(2) Barnyard manure, or some manure of a similar nature, should form the basis of manuring in Egypt.

(3) Leguminous forage crops form an excellent preparation for a good cotton crop, but to obtain the best results the soil should be ploughed up some time before cotton planting takes place.

(4) The fullest advantage of the use of these manures, as well as of any chemical fertilizer that may be employed, can

be obtained only when the soil is well prepared, deeply cultivated, and the crop judiciously watered during growth. Frequent hoeings also keep the crop in a gradually progressive condition.

(5) In addition to the use of barnyard manure at the rate of 10 or 15 tons per acre, applications of chemical fertilizers are attended with profit.

(6) Phosphoric acid at the rate of 400 ℔. per acre, applied in the form of soluble phosphate, gives excellent results. It tends to check excessive growth, increases the yield, improves the staple, and hastens maturity.

(7) A subsequent dressing of soluble nitrogenous manure is attended with excellent results. A good mixture in Egypt consists of about 125 ℔. of nitrate of soda and about 50 ℔. of sulphate of ammonia. Where larger quantities of barnyard manure are employed it may be advisable to omit the latter. The soluble nitrogenous manure is best employed in two applications.

(8) Potash manures in Egypt have not given any increase in yield, and their value is problematical. Their effect on the quality of the fibre has not been accurately determined.

CANNING PINE-APPLES.

The question is frequently asked: Why do the West Indies not establish a fruit-canning industry? So far, no practical results have followed the suggestions which have been put forward with this object.

The pine-apple is the fruit that would be most likely to lend itself for this purpose.

An essential requirement for carrying on a remunerative export trade in fresh pine-apples is that there should be an absolutely regular steamship communication between the producing country and the nearest market. Any long interval between the shipments when the crop is ripening would mean that a large quantity of fruits would be thrown on the hands of the grower, of which he might not be able to dispose. When such difficulties arise, the possibilities of a canning factory naturally come up for consideration.

For some years a considerable trade has been carried on in Antigua in the shipment of fresh pine-apples. Thus, in the year 1902-3, 4,754 barrels and 47 crates, of the value of £2,280, were exported. The trade has not been a remunerative one and is in danger of extinction. Recently, it has been suggested that a small factory might possibly be erected in the island for preserving and canning pine-apples.

In order that a factory of suitable size could be successfully operated, it would be absolutely essential that a considerable area should be established in pine-apples. Such a factory could not be run without a regular supply of fruit exactly suited for the purpose. Large canneries use from 25,000 to 50,000 pine-apples a day. It is suggested that a factory need not necessarily confine itself to pine-apples. Smaller factories that put up other fruit during the year would doubtless be able to take care of the supply of small pine-apples or those which, for any reason, could not be shipped in the fresh state. It is considered that the establishment of canning factories on a large scale would be opportune only where there is a fairly abundant supply of cheap labour.

There is no doubt that, where a good market exists for the fresh fruit, it would be desirable that only the smaller fruits, which could not be profitably exported, should be retained for preserving purposes. The prices that a factory could offer for fruit of this class would be nominal; probably not more than, if as much as, the growers obtain at present, but the latter would have a steady market and a certainty of disposing of all their fruit as it ripened. The canneries of the large sea-port cities of the United States are able to pay only the lowest price, so that they are obliged to use small fruit or that from an over-stocked market.

The canning of pine-apples is operated on a large scale in Florida, Australia, the Straits Settlements, and, of late years, also in the Hawaiian Islands and the Bahamas. It would be necessary, in the event of an attempt being made in the West Indies to establish a similar industry, to enter into competition with those countries. It is probable that the success of this industry in the Straits Settlements, whence no fewer than 443,000 cases of preserved pine-apples (valued at close on £521,000) were exported in 1904, has been largely due to the advantage conferred by an abundant supply of cheap Chinese labour. In the Hawaiian Islands four canneries are working. The output in 1904 was some 20,000 cases, each containing twenty-four cans; the following year the output was estimated at 65,000 cases.

Some ten years ago the canning of pine-apples was commenced in the Bahamas, and the canning industry has now largely superseded the export of fresh fruit. The popular fruit for canning purposes in the Bahamas is that known as the Red Spanish. This is a medium-sized to small fruit, of somewhat variable shape, and of a reddish-yellow colour. It is a hardy sort with a moderately good flavour, a prolific cropper, ripening early. The Red Spanish is the variety most extensively grown in the United States, where it may be considered the standard variety for field culture.

With the view of placing before pine-apple growers and others in the West Indies as full information as possible in connexion with this matter, the following facts with regard to the pine-apple canning industry in the Bahamas have been collected from official reports. These are supplemented with information in regard to the operations of the industry in the Straits Settlements and the Hawaiian Islands;—

CANNING PINE-APPLES IN THE BAHAMAS.

Factories for the canning of pine-apples have lately been established at Nassau and Eleuthera, and in 1897 they shipped more than 20,000 cases of preserved fruit.—(Bahamas, *Colonial Report*—Annual, 1897.)

In connexion with the purely agricultural industry of raising pine-apples and other fruit for export, there are factories for turning out the tinned fruit, and of these factories one is to be found in Nassau, New Providence, three at Governor's Harbour, Eleuthera, and one at Rock Sound, Eleuthera. At the Nassau factory the whole process is conducted in covered sheds on the wharf, so that the fruit can be landed from the schooners and at once placed on the tables to pass through the several stages by which the whole fruit is converted into the tinned product ready for export with incredible speed. The rind is first removed by hand, and the core is immediately afterwards scooped out by a machine, and the fruit cut up into disks, which are then fitted into round tins of corresponding size. Sugar is added, and the tins are then soldered up, labelled, and packed in cases for export. The refuse is thrown into the harbour, and, as the tide ebbs and flows twice daily with a very strong current, there is no inconvenient result from this practice. Mr. Parr, the Resident Justice of the Governor's Harbour district in Eleuthera, reported, at the end of June 1900, that more pine-apples had been exported that season than in any former season. The exports from that port alone consisted of 220,300 dozen, as against 197,990 dozen in 1899, and 5,630 dozen were shipped to Nassau for factory use, as against 11,600 in 1899, but the factories at Governor's Harbour itself are now packing on a more extended scale. A rough estimate of the number of pine-apples used at the two factories (Governor's Harbour) would account for another 40,000 dozen. Even before the close of the season, 4,511 cases of canned pine-apples had been exported to America from Bowles' factory, valued at £2,245.—(Bahamas, *Colonial Report*—Annual, 1900.)

The most important of the industries in which agriculture plays a part continues to be the raising of pine-apples for export in the natural state and also for the canning factories, where, after undergoing various processes, the fruit is converted into the tinned article, for which there is a large sale in the United States, as shown by the export returns. There is nothing special to remark of the crop or exports of 1901. Nothing is going on during the first quarter of any year, so that the export return as regards pine-apples is not affected by the inclusion in the return of the first quarter of 1902.—(Bahamas, *Colonial Report*—Annual, 1901-2.)

The cultivation of pine-apples for export is becoming more precarious as an industry than it was formerly. A heavy duty in the United States operates to the disadvantage of the Bahamas exports, which have to compete with those of Cuba, which are admitted free, and are of a larger and more marketable size. The Bahamas pine-apple, however, is better suited in size and quality for canning, and factories are now doing

a larger business than ever before. The most important canning factory is that of the J. S. Johnson Company, in Nassau, which expects to pack and export 50,000 cases this year.—(Bahamas, *Colonial Report*—Annual, 1903-4.)

Both pine-apple canning and extraction of sisal fibre and packing for market are industries which depend, in the first instance, on agriculture, as the factories obtain their supplies of raw material from the fields. Pine-apple canning is taking the place of the export of fruit, and the Nassau factory of the J. S. Johnson Company exported 47,973 cases, consuming 15,329 dozen pine-apples, and giving employment to 300 persons weekly ; at Governor's Harbour, Eleuthera, the canning factory worked for forty days, and filled 22,450 cases, consuming 10,000 dozen pine-apples, and giving employment to 150 persons daily. Great hopes are entertained that the pine-apple industry may be saved with the aid of scientific methods, especially since the canning industry has so largely superseded the export of raw fruit, and the fruit is reckoned superior to that of other countries for the purpose of packing and tinning.—(Bahamas, *Colonial Report*—Annual, 1904-5.)

EXPORTS OF PINE-APPLES AND CANNED PINE-APPLES FROM THE BAHAMAS.

Year.	Pine-apples.		Canned Pine-apples.		Total value.
	Dozens.	Value.	Cases.	Value.	
		£		£	£
1900	602,751	59,191	41,913	8,836	68,027
1901-2*	380,094	28,892	41,055	8,797	37,689
1902-3	521,482	36,957	47,892	9,515	46,472
1903-4		24,471	...	7,582	32,053

* Fifteen months.

CANNING PINE-APPLES IN THE STRAITS SETTLEMENTS.

The following information is extracted from the *Agricultural Bulletin of the Straits and Federated Malay States*, Vol. III, Part 1, February 1904 :—

'The pines are here always peeled by hand, though machines for this purpose have been invented, as it is found more economical to use hand labour here where it is cheap. The peelers are Chinese. They cut the top and bottom off the pine and peel it with a knife, holding the pine in the left hand, which is covered with an India-rubber glove, to protect it from the acid action of the pine juice. The gloves have constantly to be renewed as they are soon destroyed by use. The pines are then

put in the tins which are filled up with either water or syrup. The cores are removed previously, if required, by a tin tube which is pressed through the centre, but most pines are tinned without coring. The syrup is made of 3 catties [4 ℔.] of sugar to 1 picul [133⅓ ℔.] of water. After the pine is put in the tin it is soldered up, and a number of tins are put on a kind of wooden raft and plunged in a tank of water heated by steam. They are boiled in this tank for from ten minutes, in the case of the smallest tins, to an hour and a half for large tins. The biggest tins weigh 5 ℔. when full. After removal from the boiling water a puncture is made in the top of the tin with a hammer and punch, and in large tins two punctures. This is to let out the steam, and after this, the holes made are re-soldered and the tins plunged again into boiling water for nine minutes. They are then labelled and packed for export.

'The object of tinning without sugar is to avoid duty on sugar, and also to enable confectioners to use them for their purposes. Pine-apple juice is often added in the case of pines not preserved with sugar, but the tins are often filled with plain water. Other forms of exported pines are in slices, ½ inch thick (sliced pines), and with the eyes removed (eyeless pines). Bruised pines and others are often cut into chunks or cubes. All these are tinned in the same way. Grated or jam pine is another form of export. Crystallized pines are dried in the sun, and then crystallized in sugar.'

CANNING PINE-APPLES IN HAWAII.

In regard to the trade in canned pine-apples in Hawaii, the *Consular Report* on the trade of Hawaii (Annual Series, 1903-4) has the following :—

'An export coming into considerable prominence is that of pine-apples. The export of the fresh fruit is checked somewhat by the irregularity of steamers sailing to the Pacific coast, as a long interval at the height of the season, when the crop is ripening rapidly, throws a large quantity on the hands of the grower, which he may not be able to dispose of locally.

'The development, on the other hand, of the canning industry should be watched with interest, especially by canneries in the Straits Settlements.

'About 415 acres, principally in Oahu, are now planted out with over 3,000,000 plants. Four canneries are working, two having been started during the past year, and the other existing ones enlarged. The output of canned pine-apples in 1903 was about 8,000 cases (one case contains twenty-four cans, averaging 2 ℔. each); that of 1904, some 20,000 cases, and the output for 1905 is estimated to reach 65,000 cases.'

In the *Consular Report* for the year 1904-5 the following reference is made to this industry :—

'This export promises to increase considerably in the future, the output of canned pine-apples having risen from about 8,000 cases in 1903 (one case contained twenty-four cans

averaging 2 ℔. each) to some 20,000 cases in 1904. For 1906 the estimate is 12,000 cases (holding each one dozen glass containers) equal to about 135 tons, besides 165 tons of fresh fruits.'

In an interesting article on pine-apple cultivation, in the *Hawaiian Forester and Agriculturist* (December 1904), the following reference is made to the methods of canning in vogue in the Hawaiian Islands :—

'Perhaps the most important thing in connexion with this industry is to have an efficient canning plant, for, as has been said before, the shipping of fresh pines has many drawbacks; but given enough growers in one neighbourhood to support a well-equipped cannery, then, with reasonable effort, success ought to be assured. Without any desire to advertise any particular system of canning plant, it may not be amiss to say that the "Baker Process" is a very convenient one, so far as cooking the fruit is concerned, and there may be others quite as good.

'This is the one that was installed by the Hawaiian Fruit and Packing Company, Limited, of which the writer was manager. It had a capacity of 10,000 cans per day, and as the processing could be regulated to a nicety, the output was entirely uniform. Much testimony was received by us that no pines had ever been put on the American market that could come near ours in quality.

'The last shipment made by us brought $2·35 per dozen cans, of 2½ ℔. each, ex ship at San Francisco. We sold out our pine-apple business in order to engage in the raising of sugar-cane, which was at that time more profitable. As improved machinery for the making of cans, etc., is frequently coming into use, the writer would not wish to be considered as an authority for saying exactly what would be the most improved outfit in establishing a cannery at the present time, but the essentials remain the same. The double-seaming machine for putting the tops on the cans, seems to be the most striking improvement; this is a great help, for by the old plan the most difficult part of the work was to seal the head of the can when it was full of fruit and juice. Some of our own contrivances were ahead of anything that has come under my observation since, especially for sizing the fruit.

'Besides the can-making machinery, the modern cannery has machines for paring, coring, sizing, and slicing the pines. The processing should be done by sending the cans, which are placed in trays, about a dozen to each tray, through a heater, called the exhaust, which is kept just below the boiling point, on a carrier consisting of an endless chain. On emerging from this the cans are punctured and dotted, and are now ready for the actual cooking. This is done by starting them on a carrier again, through another kettle, which must be carefully kept at 212° F., or boiling point. Any neglect of this important particular spells disaster. Another thing to remember is that the pines should not be boiled more than fourteen minutes, for if they are the quality will be very much lowered. Some amateur canners (in other countries) are boiling their pines twenty-five or thirty minutes, which makes them unfit to eat by comparison.

On coming out of the boiling kettle the cans should be put away on a clean floor, one tier only if there is plenty of room, otherwise they may be placed on shelves, to allow them to cool reasonably quick. When cold, they must be gone over with a sounding iron to test them for leaks, and if any are found they must be mended at once, and the tins again sent through the exhaust. As soon as you are sure that there are no more leaks, the cans should have their ends dipped in lacquer to prevent rust, and the labels put on, when the best plan will be to put them in their travelling boxes, and send them to the consumer. The size of the building will have to be determined largely by the amount of machinery required to take care of the crop, but it is advisable to err, if at all, on the side of liberality, and as the interior of the cannery must be kept scrupulously clean, it will be better to have a lean-to shed in which to receive the pines as they come from the field: the ends should be cut off here and the pines sent down through an inclined shute to the work bench within the cannery. No pine should be gathered for canning until it is ripe enough to be eaten fresh, and nothing but its own juice should be used for syrup, no matter what anybody may say to the contrary; this will pay in the long run.'

FRUIT-CANNING FACTORY IN JAMAICA.

It is of interest to add that, since the foregoing was written, a fruit-canning factory has been established in Jamaica. A recent issue of the Jamaica *Daily Telegraph* (June 28) contains a description of the operations at this factory, which has been established by the Norbrook Canning Company.

The prime mover in this enterprise is Mr. G. Loutrel Lucas, who has been engaged in pine-apple growing—in Florida and Jamaica—for twenty-three years. For some time his efforts as a grower and exporter of pine-apples in Jamaica met with success, but the irregularity in the sailings of the vessels, which then existed, and other difficulties caused him to turn his attention to converting his fruit into preserves.

The factory is reported to be a building 150 feet long by 46 feet in width. While pine-apples are receiving primary attention at this factory, mangos, guavas, limes, and many other tropical fruits are being preserved in one way or another. The development of this enterprise, which, so far as is known, is the first venture of the kind in the West Indies, will be watched with much interest.

The following account is given of the methods adopted in canning pine-apples:—

'On a large stand there were about 200 pines of the finest varieties cut and ready to be peeled. From this stand one by one they were taken and attached to a machine, where the skin was removed in quick time. Thence the pine passes on to a corer, and it is here that the "eyes" and other rough parts of the fruit are removed. The meat is now clean, and it next goes into a slicing machine, where it is sliced to the shape of a 2-lb.

tin. The slices are laid out on a sorter, and they are sorted into two grades. The first grade consists of slices of the fruit which have come out a perfect circle, whilst the second grade is made up of slices not quite so perfect. The first grade of the article is put up in large cans, whilst the second grade is stowed in half-sized cans. These cans are taken to a big kettle, where syrup is poured on the stuff. This is not all. After the cans have been filled they are put into a steam box, and in rapid succession each tin passes through. Here each tin receives its head; and on the cap machine the cover is laid on; by the manipulation of a spring it is pressed down, and so the tin is sealed. It will thus be seen that the contents of each can are warranted in every respect. What is used throughout the factory is the sanitary can, sealed by special machinery without acid or solder. After the cans have been sealed, they are put into a kettle of boiling water, and by this process the stuff inside is boiled. The temperature of the water in the kettle goes up to 270°; but, of course, can be reduced according to requirements. After remaining in the kettle for some little time, the cans are next taken out and put into a tank of cold water for the cooling process. Later on, in the store-room, the tins are polished and labelled. The article is now ready for exportation; but as a rule each tin is kept in the factory for a few days.'

PRODUCTION OF CAMPHOR.

Camphor trees grow well in the West Indies and are to be seen in several of the Botanic Gardens and Stations. A few trees have also been raised by private persons. Mr. J. H. Hart stated at the West Indian Agricultural Conference, 1902, that some of the trees planted at the Trinidad Experiment Station three years before were then over 10 feet in height. Mr. Hart exhibited a sample of crude camphor distilled from the wood of one of the trees in the gardens.

The following information, extracted from the *Bulletin of the Imperial Institute* (Vol. III, pp. 353-63) is likely to be of interest to those who have conducted experiments in the cultivation of camphor trees in the West Indies:—

The establishment of the camphor monopoly in Formosa and its more recent extension to Japan have led to a considerable increase in the price of camphor, and as a result the attention of many planters in British colonies and dependencies, notably India and Ceylon, has been drawn to this product, and a number of inquiries have been received at the Imperial Institute for information relating to various matters connected with the cultivation, production, and preparation of this

product. In these circumstances it has been considered advisable to prepare a general statement giving such information as is available on the subject, and dealing not only with the naturally produced camphor, but also with the manufacture by chemical means of 'synthetic camphor,' which has recently appeared on the market, and with the so-called 'artificial camphor,' which has been used from time to time as a substitute for true camphor.

The term 'camphors' has been applied in a general sense to a group of naturally occurring compounds containing carbon, hydrogen, and oxygen, which are related somewhat closely to that class of hydrocarbons known as the 'terpenes,' of which oil of turpentine is a well-known type. Using the word in this broad sense, 'camphors' are volatile substances possessing characteristic odours; they are mostly crystalline solids, insoluble in water, but easily soluble in alcohol. Almost all the 'camphors' occur in plants, together with the hydrocarbons to which they are closely and probably casually related. Both the hydrocarbons and the oxygenated bodies are volatile in steam, and the process of steam-distillation is often made use of in separating these constituents from the plant substance in which they are found.

In a narrower sense, however, and, as a matter of fact, in the sense in which the word is ordinarily used, by camphor is always understood the well-known laurel or Japan camphor, the product of the *Cinnamomum Camphora*.

Many references to camphor are found in the writings of the ancients, by whom it was greatly valued as a rare perfume, and it is often included in their lists of costly possessions. The camphor, however, referred to by the earlier Chinese and Arabian writers was probably another variety known at the present time as Borneo camphor or borneol, which is the product of the tree *Dryobanalops aromatica*, and is also found in small quantity in *Blumea balsamifera*. This variety, even at the present time, is almost all consumed in the East, and very little of it finds its way into the European markets. The exact date of the introduction of laurel camphor into Europe is not known, but it was apparently in use, and its value as a medicine recognized, as early as the twelfth century.

Common Japanese or laurel camphor is the product of the *Cinnamomum Camphora*, an evergreen of the family *Lauraceae*, which occurs native along the eastern side of Asia from Cochin China to Shanghai, and in the islands from Hainan to South Japan. The tree is particularly plentiful in the island of Formosa, where it covers the whole line of mountains, which runs from north to south, up to an elevation of 2,000 feet above the level of the sea.

It forms a large and handsome tree, which, in its native country, attains a height of 100 feet, having a trunk 2 to 3 feet in diameter. The leaves are of moderate size and laurel-like in appearance, and when crushed smell strongly of camphor; the stem affords excellent timber, much prized on account of its odour, for making clothes-chests and the drawers of cabinets. The tree is largely planted in Ceylon for ornamental purposes.

The camphor is found in all parts of the tree; the relative proportions in different parts appear to be affected by the age of the plant and the district in which it is grown.

Almost all the camphor of European commerce comes from Formosa and Japan, a comparatively small quantity being supplied by China. For many years, in fact to within quite recent times, it was prepared from the wood by a somewhat crude and wasteful process, but since the Japanese Government has taken over the industry in Formosa and established a government monopoly, the processes now in vogue are much more economical. Previously, the wood was cut into small chips from the trees by means of a gouge with a long handle, and these chips were then exposed to the vapours of boiling water. The camphor volatilized with the steam, and, on cooling the vapours, the camphor was deposited together with a quantity of oil, water, etc., which were to some extent removed by draining. For this purpose of treating the chips with steam, crude stills were constructed out of the hollow trunks of trees; these were arranged over a furnace, the wood being protected by a coating of clay. Water was poured into the 'still' and a board perforated with small holes was luted on the top. The chips were placed in small bundles immediately over the perforations and these were then covered with earthenware pots. A fire having been lighted in the furnace, the water became heated, and the steam passing through the chips carried with it the camphor, which was deposited in minute white crystals in the upper part of the earthenware vessel. The camphor thus obtained in a moderately pure condition was removed from the pots every few days. Four stills, each having ten pots placed in a row over one trough, were generally arranged under one shed, and the stills were moved from time to time as the wood in the locality became exhausted. In some cases, however, the camphor was not extracted on the spot, the chips being conveyed to the towns and submitted to a less wasteful process of extraction. In many of the towns metal stills were used, and the steam distillate was passed along a pipe—generally bamboo canes were used—into a receiver, which often consisted of a tub in the upper portion of which straw was placed. The camphor condensed on the straw, the oil and water draining off into the lower portion. Recently, however, the methods have been greatly improved, both in regard to economy of production and to the purification of the product.

In the first place, the camphor wood is now submitted to the action of steam over roughly built, though efficient, furnaces, and the camphor is condensed in cooled wooden vessels. It is then freed from the oil by draining, and the product thus obtained is known as crude or *Grade* '*B*' camphor. For the production of refined or *Grade* '*A*' camphor, the crude material is heated in large iron retorts through which a current of air is passed. For the first forty-eight hours only sufficient heat is applied to drive off the water and oil; the retorts are then connected to a condensing chamber, the roof of which is cooled by running water, and are heated to a higher temperature to volatilize the camphor. The camphor then collects in the cool

chamber in the form of small crystals or 'flowers.' It is removed, formed into blocks, and pressed, first by steam power and finally by high hydraulic pressure. It is then sold as 'refined' or Grade 'A' camphor.

CAMPHOR OIL.

In all the processes of extraction a considerable quantity of essential oil is obtained, first in the steam distillation and then from the subsequent process of draining. This is known as *Camphor oil.* As would be supposed, this contains a considerable quantity of camphor in solution which can be partially recovered by fractional distillation. Many other interesting bodies have been found to be constituents of the oil.

USES OF CAMPHOR.

As before mentioned, camphor has long been known as a perfume and has been extensively used for the prevention of insect ravages in clothing. As a drug it is largely consumed by the natives of India, and very large quantities are annually imported into Bombay and other ports. It is also used medicinally in Europe and America; it has antiseptic, sedative, and stimulating properties, and is frequently applied both internally and externally. It is interesting to notice that it has been recently used, apparently with beneficial results, by Koch in cases of tuberculosis.

Industrially, it is used on a large scale in the manufacture of celluloid, and also in the preparation of smokeless powder. *Camphor oil* has found many and varied applications. It is used by the Chinese as a remedy for rheumatism. Large quantities are worked up annually in Europe for the manufacture of safrol; it is also used in perfuming certain kinds of soaps, and, as a solvent, is used in varnishes. Like most essential oils it is a powerful germicide and disinfectant.

CAMPHOR MONOPOLIES.

As long ago as the beginning of the eighteenth century the Chinese Government endeavoured to turn the camphor forests of Formosa to account by introducing a camphor monopoly, the evasion of which was punished by death. In the year 1720, no less than 200 persons were executed for cutting down the trees without permission. This monopoly continued, though in a somewhat modified form, for a century and a half, only being revoked in 1868.

Since the island became a Japanese possession, however, the production and sale of camphor has again become a government monopoly. The monopoly came into force in August 1899. The Government granted licenses, regulated the number of stills so as to control the supply, and built a factory at Turpeh for the purification and pressing of the crude article. The sale prices were fixed and controlled by the Japanese Government. In 1900 the Government accepted the tender of an English firm to take over the production with a view to putting it on the market. The result was, of course, that, with

the chief supply thus monopolized, the price of camphor was forced up, and in a very short time the price of refined camphor had increased 100 per cent.

As might have been expected, this increased value of camphor stimulated the production in other districts than Formosa, and owing to the fact that the industry in Old Japan was still in the hands of private traders, the Formosan monopoly was greatly hampered in its endeavour completely to control the market. On the appeal of the Formosan Government, a bill was introduced by the Japanese Parliament to the effect that the camphor monopoly should be extended to Old Japan, and this was adopted in July 1903. The bill also provides for the inclusion within the monopoly of the production of camphor oil.

The terms of the bill are roughly as follows: Producers of crude camphor and camphor oil must have a license for carrying on their trade; they must keep exact accounts of the manufacture and must deliver their camphor products to the Japanese Government for which they will receive compensation at a rate fixed by the Government. The producers are not allowed to refine crude camphor; this is the exclusive right of the State.

The Government now sells the camphor, which it has acquired mostly at a fixed price, and reserves the right to restrict the production when the state of the market renders it necessary.

The monopoly in the camphor industry has exerted a powerful influence on the world's trade in this product, and as the European demand is continually increasing owing to its industrial applications, the question of the cultivation of the camphor tree in other tropical regions has been seriously considered. It has already been successfully cultivated in Ceylon, India, Australia, Florida, and California. In a circular published from the Royal Botanic Gardens of Ceylon, Messrs. Willis and Bamber, the Director of the Gardens and the Government Chemist, respectively, have laid before the planting public in Ceylon the results of some apparently very satisfactory experiments indicating the methods of cultivation and preparation which had been found best suited to Ceylon.

CAMPHOR CULTIVATION IN CEYLON.

Cinnamomum Camphora was first introduced into Ceylon by the Royal Botanic Gardens in 1852. In the autumn of 1893 seeds were obtained from Japan, and the plants resulting from these were, in 1895, largely distributed to planters and others in the island. Subsequently Mr. Nock, Superintendent of Hakgala, collected information about these trees (about 950) and reported as follows:—

'During 1895 plants of camphor were distributed from Hakgala to planters in various parts of the island, at elevations ranging from 250 to 6,540 feet, with annual rainfalls varying from 54 inches on 104 days to 217 inches on 212 days.

'Replies as to the growth of the trees have been received from thirty localities, and I think it is pretty well proved that

under certain conditions of soil and climate, camphor will thrive at all elevations in Ceylon, from about sea-level to the highest mountains.

'It appears to thrive best in a well-drained, deep, sandy loam in sheltered situations with a rainfall of 90 inches and over, and dislikes poor or close, stiff, undrained soil. The growth is slow in sterile soil, but, under favourable conditions, in good soil is very rapid, the tree reaching a height of 18 to 20 feet in five years, with a spread of branches of 8 to 12 feet and a stem 6 to 7 inches in diameter. This compares very favourably with the growth of the trees in their native habitat, where a tree 30 feet high and 6 inches in diameter at ten years old is considered good. The best five-year-old tree (from planting) in Ceylon is at Veyangoda, at an elevation of about 100 feet, with a rainfall of about 100 inches on 180 days. It is 25 feet high and growing luxuriantly. The next best are at Hakgala, where the largest is 20 feet high, with a spread of 13 feet and a stem diameter of 7½ inches at the ground.

'The habit of the trees in Ceylon in good soil is bushy, with a tendency to throw up many stems. This is a point of importance as it shows that the tree will coppice well and stand frequent cuttings and prunings, and possibly even plucking of the "flush" as with tea. In close, hard, undrained, or stiff clayey soil, the growth is poor and the habit stunted or dwarfed, and this is also the case in exposed wind-blown situations.

'Of course, it is only in the experimental stage here yet, but judging from my experience of it for some years, it is my opinion that as a minor product it should be grown in the form of hedges, planted at distances of 6 to 9 feet apart, and 2 to 3 feet apart in the row. The rows should run north-west and south-east or across the direction of the prevailing winds, and the plants should be allowed to grow 6 to 9 feet high. Planted in this way there would be ample room for cultivation, and each row would shelter the other from the north-east and south-west winds, besides forming a large surface for clipping. As the young shoots appear to yield the most camphor, the crop could be obtained by clipping the hedge with a pair of light shears, and the expense would be very slight. The trees might also be planted at 6 feet apart and treated in the same way as tea bushes, or they might be planted 12 feet apart and trained as pyramids, or, again, planted 4 feet apart and alternate plants coppiced in alternate years.'

PROPAGATION, CULTIVATION, ETC.

Mr. Nock states: 'Camphor plants are best and most easily propagated from seeds. The seeds do not keep well, and should be sown as soon as possible after ripening. They ripen in Japan, which at present is the only important source of seed, in October and November, and should be ordered some time in advance so as to obtain them as soon as they are ripe. I find it a good plan to soak the seed in water for twenty-four to forty-eight hours before sowing, agitating the water occasionally. The best seeds being heavier will sink to the bottom,

and these should be sown thinly by themselves; the lighter ones should be sown thickly, as only a small percentage will germinate.

'The seeds should be sown in well-prepared beds of sandy loam and leaf-mould; they should be sown from $\frac{1}{2}$ to $\frac{3}{4}$ inch deep, making the bed firm but not tight. The beds should be kept shaded and just moist. Too much wet will cause the young seedlings to damp off, and if allowed to get too dry the germs will quickly dry up and die.

'We have been most successful when the seed has been sown in boxes (made of $\frac{1}{2}$-inch wood), 18 by 13 by $3\frac{1}{2}$ inches, filled with the kind of soil described above. The boxes are handy to lift about, and can be easily protected from heavy rain and strong sun. Sheds made after the style of the old cinchona seed sheds answer very well for standing the boxes in, and if made light and airy would do well to sow the seeds in direct, but care should be taken not to allow the young plants to be "drawn."

'We find it a good plan to prick out the seedlings into supply baskets as soon as they are large enough to handle comfortably, or transplant them into beds, placing the plants 6 inches apart every way, and keeping them shaded and watered until they begin to grow, when they will bear the full light of the sun, but will require to be freely watered in dry weather.

'When the plants are from 9 to 15 inches high they are at their best for final planting, but if the weather is unsuitable they may be kept in the nursery till they are 2 feet high, or until good planting weather occurs, viz., dull, showery weather. In such weather they require very little shading and soon take hold of the soil.

'Cuttings do not strike root readily, and only under certain conditions will they be successful. If the prevailing weather should be too dry they soon go off, and if too wet and cold, they decay before the roots are formed. We have had batches of cuttings with 70 per cent. beginning to "callous" over and young shoots forming, that have gone off after three or four days of rough weather—cold high winds and heavy rains—and others that have gone the same way after a week of dry sunny weather. The favourable conditions are equable heat, light, and moisture; with these, and wood for cuttings in a proper state, a large percentage will strike root and make good plants.

'The nursery beds for seeds as well as cuttings should be made in a well-drained situation, and as near water as possible. The beds may be any length and from 3 to 4 feet wide. The soil for cuttings should be composed as follows: One part good sandy loam, one part leaf-mould, and one part clean, sharp sand (to this it would be beneficial to add a good sprinkling of powdered charcoal), all thoroughly mixed. The soil should be 6 to 9 inches deep. A layer of good sharp sand 1 inch thick should be laid on the surface. As a protection against hot sun and heavy rains, it would be well to put a roof of thatch over the beds in the form of a shed, but it should be constructed

with open sides to allow plenty of light and air. A shed 4 feet wide, with a lean-to roof on stout posts, open at the back and front, will be found a useful size. The posts should be 6 feet high in front and 3 feet 6 inches at the back. The roof may be thatch shingles, or other light material. If more than one are required, a space 4 feet wide should be left between the sheds to give room for watering, weeding, and general attention.

'The best material for cuttings is that from straight, healthy, and well-matured shoots of the current year's growth, not too soft or too hard. If too hard, they will not root readily, and if too soft they will be liable to damp off. The cuttings may be of any size from the thickness of a lead-pencil to $\frac{3}{4}$ inch in diameter. They should be cut into lengths of from 6 to 9 inches. A clean cut with a very sharp knife immediately below a joint to form the base of the cutting is of the greatest importance. If the cut portion is torn or jagged, or too far away from the joint, it is almost certain to decay, though it may remain green for a long time.

'The operation of inserting the cuttings is best done by opening a trench with a sharp spade so as to form a straight edge. The prepared cuttings should be laid against this and the soil pressed firmly round them. They should be placed in rows 9 to 12 inches apart, and 3 inches apart in the rows, and at a sufficient depth to leave only two or three buds above the surface.

'The sooner the cuttings are made and put in after being taken from the trees the better. After the cuttings are put in, the beds should be watered to settle the soil, and if in the open they must be carefully shaded, and sunlight must be only gradually let in as they become rooted and can bear it.

'If all goes well, they should be rooted in two to three months, but they will not be ready for planting out for three or four months.

'Camphor may also be propagated by "layers." The operation of "layering" is very simple. The shoots should be bent down to the soil. The branch at the bend should be cut halfway through, then cutting upwards for about $1\frac{1}{2}$ to 2 inches, so as to form a tongue. The cut portion must be kept apart by a slight twist, or by placing a small stone in the cleft. The shoot should then be pegged down firmly into a groove made in the soil for its reception and covered with soil. The end of the shoot must be kept upright by tying it to a stick.

'Another simple way is to split the branch at the bend where it is to be laid in the ground, making the split about 2 inches long and keeping the cut parts open by inserting a piece of wood or stone. Peg down well into the soil and stake. The ends of the shoot should be cut back a few inches with a sharp knife.'

SYNTHETICAL CAMPHOR.

In 1900 a process was patented by the Ampère Electro-Chemical Company, of New Jersey, for the manufacture of

camphor from oil of turpentine, and in 1903 a new company, the Port Chester Chemical Company, was formed to manufacture camphor by this process.

In general terms, the process is as follows: By heating turpentine with anhydrous oxalic acid two compounds are formed, viz., bornyl hydrogen oxalate and bornyl formate, which, when subjected to steam distillation in the presence of alkali, yield camphor and borneol, respectively. Borneol is readily converted into camphor by oxidation, so that on treating the mixture with an oxidizing agent almost the whole of the product is obtained as camphor.

The mixture of turpentine and anhydrous oxalic acid is heated in steam-jacketed tanks, and when the reaction is complete, the liquid mass is pumped into stills, alkali is added, and the mixture is distilled by the aid of live steam. From the distillate the mixture of borneol and camphor is recovered by fractional distillation.

The crude product is filter-pressed, washed free from all traces of oil, and treated with an oxidizing agent to convert the borneol into camphor. The crude camphor is centrifugalized and then purified by sublimation. The yield of camphor is said to be 25 to 30 per cent. of the weight of the turpentine.

It will be seen, however, that this process depends on the low price of turpentine for its successful competition with the Formosan natural product, and also on the utilization of by-products. This process is at a great disadvantage at present owing to the high price prevailing for oil of turpentine.

ARTIFICIAL CAMPHOR.

Many attempts have from time to time been made to find a good substitute for camphor, for the manufacture of celluloid, and at one time the substance known as 'artificial camphor' was used to a considerable extent for this purpose. This substance—really a terpene hydrochloride—is obtained by passing hydrochloric acid gas into well-cooled oil of turpentine or pinene and subsequently purifying the crystalline product so obtained. Although possessing physical properties similar to those of camphor, it differs very greatly from it in chemical composition, containing, as it does, chlorine. Recently, naphthalene has also been applied in this connexion and has, it is stated, in some cases, been found to be a satisfactory substitute.

At present there seems to be little prospect of natural camphor being largely replaced by either 'synthetic camphor,' or a camphor substitute, since the only product—oil of turpentine—which, so far as is known at present, can be used as a source of these materials, is becoming most expensive, owing to the demand exceeding the supply. Further, it is probable that natural camphor could be placed on the market at prices much below those now prevailing, and still prove remunerative to exporters, and it is doubtful whether 'synthetic camphor' could, under such conditions, compete with the natural product in price.

The Division of Botany of the U.S. Department of Agriculture issued, in 1897, the following paper (prepared by Mr. Lyster H. Dewey) on the camphor tree. It contains, in addition to a general description of this tree, the methods of extraction of camphor, and the uses of its products, some of the results of the experimental cultivation of camphor trees in the United States:—

DESCRIPTION.

The camphor tree is a broad-leaved evergreen, related to the red bay and to the sassafras of the United States. In its native habitat it attains a height of 60 to 100 feet, with wide-spreading branches and a trunk 20 to 40 inches in diameter. Its general habit is similar to that of the bass-wood. The leaves are broadly lanceolate in form, with acuminate points at both base and apex, of a light-green colour, smooth, and shining above, and whitish, or glaucous, on the under surface. The lower pair of lateral veins is more prominent than the others, but the leaves are not as distinctly three-nerved as those of the cinnamon and many other species of the genus. The small white or greenish-white flowers are borne in axillary racemes from February to April on shoots of the previous season, and are followed in October by berry-like, one-seeded fruits about $\frac{3}{8}$ inch in diameter. The fruiting pedicels terminate in a saucer-shaped disk, persisting after the mature fruit has fallen.

NATIVE RANGE.

The camphor tree is native in the coast countries of eastern Asia, from Cochin China nearly to the mouth of the Yang-tsze-kiang, and on the adjacent islands, from the southern part of the Japanese Empire, including Formosa and the Ryukyu Islands, to Hainan, off the coast of Cochin China. Its range also extends into the interior of China as far as the province of Hupeh, about 500 miles from the coast on the Yang-tsze-kiang, in latitude 30° north. This area, extending from 10° to 34° north latitude and from 105° to 130° east longitude, is all embraced in the eastern monsoon region, which is remarkable for abundant rains in summer.

The camphor trees growing wild in the native range are usually most abundant on hillsides, and in mountain valleys where there is good atmospheric as well as soil drainage. The temperature in the greater part of this region, which is partly within the tropics and partly subtropical, rarely falls below freezing point. The tree is an evergreen, changing its leaves generally in April, and therefore the winter temperature is a factor of more importance than would be the case with a deciduous tree.

RANGE UNDER CULTIVATION.

Notwithstanding the comparatively narrow limits of its natural environment, the camphor tree grows well in cultivation under widely different conditions. It has become abundantly naturalized in Madagascar. It flourishes in Buenos Ayres.

It thrives in Egypt, in the Canary Islands, in south-eastern France, and in the San Joaquin Valley in California where the summers are hot and dry. Large trees, at least 200 years old, are growing in the temple courts at Tokio, where they are subject to a winter of seventy to eighty nights of frost, with an occasional minimum temperature as low as 12° to 16° F. The most northern localities in the United States, so far as known at this Department, where the camphor tree has been grown successfully out of doors, are Charleston and Summerville in South Carolina, Augusta, Ga., and Oakland, Cal.

At Charleston, Summerville, and Augusta, the trees have withstood a minimum temperature of 15° F., but they have been protected by surrounding trees and buildings. At Mobile, Ala., the trees have grown and fruited in protected situations, while in exposed places they have been repeatedly destroyed by frosts. While the camphor tree will grow on almost any soil that is not too wet, it does best on a well-drained sandy or loamy soil, and it responds remarkably well to the application of fertilizers. Its growth is comparatively slow on sterile soils, but under favourable conditions it sometimes grows very rapidly. An instance is recorded of a camphor tree in Italy 1 foot in diameter and 90 feet high, eight years from the seed. Under ordinary conditions, however, such a girth is not often attained in less than twenty-five years, and such a height is rarely attained in a century. A tree planted at New Orleans in 1883 is now 40 feet in height, with a trunk 18 inches in diameter at the base, and 8 feet to the first limbs. Under favourable conditions an average of 30 feet in height, with trunks 6 to 8 inches in diameter at the base, may be expected in trees ten years from the seed.

USES OF THE TREE AND ITS PRODUCTS.

The principal commercial uses of the camphor tree are for the production of camphor gum and camphor oil. Camphor gum is employed extensively in medicine. It enters into the composition of many kinds of liniments for external application. For liniment it is used especially in combination with olive oil. It is taken internally for hysteria, nervousness, nervous headaches, diarrhœa, and diseases affecting the alimentary canal. It is a specific in cases of typhoid fever and cholera. Camphor fumes have been used with success in cases of asthma. It has been used very extensively to keep insects out of furs, woollens, etc. In Japan camphor and camphor oil are used in lacquer work. The oil is somewhat similar to turpentine. It dissolves resins and rubber, and after being separated by fractional distillation into oils of different weights, it is used in varnishes, paints, and soaps, and to protect leather against insects. In Japan and China it has been used for illuminating purposes, but it produces a smoky flame.

Among the secondary uses of the camphor tree the most important is for ornamental planting. Its bright evergreen leaves, rapid growth, and long life make it valuable for this purpose. In Japan and China it has been the principal tree planted in the temple courts for many centuries, and in those

countries it takes the place of the historic oaks of England. It has been extensively introduced into southern Europe and South America for ornamental purposes.

The wood, with its close grain, yellow colour, and susceptibility to polish, taking a kind of satin-like finish, is exceedingly valuable in cabinet work, especially for making drawers, chests, and cupboards proof against insects. The leaves and young branches, although they have but a slight odour of camphor, are packed with clothing or scattered about unused rooms to guard against insects.

The tree produces an abundance of berry-like fruits, which are used in Japan and China to make a kind of tallow. The fruits are greedily eaten by chickens and birds, especially mocking-birds, which often select camphor trees for nesting places.

CONDITIONS OF SUCCESSFUL CULTIVATION.

For most of the secondary purposes, the camphor tree may well be cultivated wherever it can be made to live; but for the distillation of gum and oil with a commercial view, and for the production of wood for cabinet purposes, it must be grown under the most favourable conditions. The minimum winter temperature should not be below 20° F., and this minimum should be of rare occurrence. The soil, preferably sandy and well drained, should be irrigated unless there are abundant rains. Fifty inches of water during the warm growing season are desirable, and much more may well be used where the air is very dry.

An abundance of plant food, rich in nitrogen, is required for rapid growth; but the kind of fertilizer that can be most profitably applied will vary according to the character of the soil in each locality. In the absence of definite information in this regard, the kind of fertilizer producing most rapid growth of wood in the orange or in other fruit trees may be taken as an index.

PROPAGATION.

Camphor trees may be grown either from seed or from cuttings. They are usually grown from seed, as the trees fruit abundantly, and seedlings can be grown more easily than cuttings. The seeds are collected at maturity in October and November, and after drying are packed in sharp, white sand or some similar material to keep them fresh until the time of planting in spring. About the last of March they are sown in drills in the seed bed.

The soil of the seed bed should be a good sandy loam mixed with about one-third leaf mould. The seed bed should be kept moist, but not too wet, and should be shaded from the direct rays of the sun if the weather is warm. The best soil temperature for germinating camphor seeds is from 70° to 75° F. The temperature of the atmosphere may be 10 degrees higher. The seedlings will grow well at higher temperatures, but are likely to lack vigour and hardiness.

The seedlings may be grown in pots, which will facilitate transplanting at any time, or they may be transplanted in nursery rows early in April when one year old. Plants two years old are generally regarded as best for final planting. At this age they vary from 20 to 40 inches in height.

PLANTING AND CULTIVATION.

When set out for ornamental purposes, the camphor tree may be expected to grow, in favourable situations, about as rapidly as a Le Conte pear, and to require about as much room. In Japan, where the law requires that a new tree shall be set out for every one cut, they are not generally set in straight orchard rows, but cultivation there is performed almost exclusively by hand labour. There are no records showing results of regular orchard planting, hence the distances at which trees should be planted must be determined by the size and form of the trees and the methods of cultivation and of procuring the gum. They may be set closely in rows about 10 feet apart, and alternate rows cut and reset every five years, thus producing bush-like plants of ten years' growth. They may be planted in checks 10 feet square, and alternate trees cut every ten or twelve years, or they may be planted in larger checks, and all of the trees be cut at the age of fifteen or twenty years.

There are not sufficient data obtainable upon which to base definite statements as to the best methods of planting or the age at which the trees may be cut with greatest profit for the production of gum. A recent English *Consular Report* from Japan states that 'although hitherto the youngest wood from which camphor was extracted was about seventy to eighty years old, it is expected that under the present scientific management the trees will give equally good results after twenty-five or thirty years.' Camphor of good quality has been produced in Florida from the leaves and twigs of trees less than twenty years old, 1 ℔. of crude gum being obtained from 77 ℔. of leaves and twigs.

The trees will endure severe pruning with little apparent injury. One-third of the leaves and young shoots may be removed at one time without materially checking the growth of the tree. The largest proportion of camphor is contained in the older, larger roots; the trunk, limbs, twigs, and leaves containing successively a decreasing proportion. When the camphor tree is killed nearly to the ground by frost, it sends up vigorous shoots from the base. It may be expected to do the same when cut, especially if cut late in the fall. Experiments are needed to determine whether this growth may be depended upon; or whether it will be more profitable to dig out the larger roots and set out new seedlings.

DISTILLATION OF CAMPHOR GUM.

In the native forests camphor is obtained almost exclusively from the wood of the trunks and the larger roots and branches. These are first chopped into small pieces and sometimes pounded or bruised to facilitate distillation. The

work is performed by hand labour, and the processes in use seem rather crude. In some parts of Formosa a layer only about an inch thick is cut from the larger roots and from part of the trunk, the object being to obtain the best camphor-bearing wood without killing the tree. Trees thus treated often die. Where trees are cut down, the best parts of the trunks are sometimes saved for lumber. From 20 lb. to 50 lb. of chips are required for 1 lb. of crude gum. Trees fifty years old in Formosa yield an average of about 133 lb. of crude gum. Many different forms of stills and different methods of distillation are employed in different districts, but all result in a separation of the gum from the wood by means of steam or hot water.

In Fukien, China, the chips are sometimes soaked in water several days, and the water, together with the chips, is distilled. The form of still in common use there consists of a metal pan to receive the water and chips, supported above a fireplace. Over this pan is placed a large cone of rice straw coated on the outside with a layer of mud. When the fire is started the steam rises in the cone, carrying with it the camphor gum, which collects in flakes on the straw. Sometimes the chips are merely steeped in water, and the gum is skimmed off as the water cools.

A common form of still used by the natives in Formosa consists of a trough, hollowed out of a tree trunk, supported over a fire, from which it is protected by a coating of mud. This trough is partly filled with water and is covered with a plank in which there are several groups of small holes. Camphor chips are piled over each group of holes and covered with an inverted earthen pot. As the water is heated the steam rises through the holes in the plank and passes through the pile of chips, carrying with it the camphor gum, which is deposited in the upper part of the pot. A form of still used by the Germans in Formosa consists of a series of fireplaces made of mud bricks supporting shallow pans of water. Above each pan and partly inclosed in the brickwork is a cylinder about a foot in diameter with a perforated bottom for holding the chips. A large earthen jar, inverted over the top of the cylinder and fitting it closely, collects the camphor, which crystallizes upon cooling. A simpler process in use in Formosa consists in boiling the chips in an iron pot, the camphor being collected in an earthen jar inverted over the top of the pot.

The most skilful methods of distillation are practised in the island of Kiu Shiu, Japan. Camphor trees, selected by a Government Inspector, are felled, and the trunks, larger limbs, and sometimes the roots, are cut into chips by hand labour with a sharp concave adze. The fresh chips are placed in a wooden tub about 40 inches high and 20 inches in diameter at the base, tapering toward the top like an old-fashioned churn. The perforated bottom of the tub fits tightly over an iron pan of water on a furnace of masonry. The tub has a tight-fitting cover which may be removed to put in the chips. It is surrounded by a layer of earth about 6 inches thick to aid in retaining a uniform temperature. A bamboo tube extends from near the top of the tub into the condenser. This consists of

two wooden tubs of different sizes, the larger one right side up, kept about two-thirds full of water: the smaller one is inverted with its edges below the water, forming an air-tight chamber. This chamber is kept cool by a constant stream of water falling on the top, running down over the sides and out through a hole in the larger tub. The upper part of the condensing chamber is sometimes filled with clean rice straw, on which the camphor crystallizes, while the oil drips down and collects on the surface of the water. In some cases the camphor gum and oil are allowed to collect together on the surface of the water and are afterwards separated by filtration through rice straw or by pressure. In another form of condenser the steam is conveyed by a bamboo tube into an inclosed tub, and from this it passes by a tube to a second tub containing several vertical partitions open at alternate ends and with screens of bamboo lattice work at intervals in the passageways. A large proportion of the water condenses in the first tub. The camphor collects on the screens in the circuitous passage in the second tub, and the oil drains down from these, collecting in the bottom.

Where the chips are distilled by steam, about twelve hours are required for the process. The apparatus is not strong enough in any case to hold steam under pressures exceeding more than 2 lb. or 3 lb., limiting the range of temperature to from 212° to 250° F.

The principles generally held to be essential in distilling camphor of good quality are: (1) The heat must be uniform and not too great, producing a steady supply of steam; (2) the steam after liberating the camphor must not come in contact with metal, that is, the tub and condensing apparatus must be of wood or earthenware.

SUGGESTED IMPROVEMENTS.

Many improvements upon the methods described can doubtless be made, tending both to a reduction in cost and an increase in the proportion of crude gum obtained. Instead of an adze wielded by hand, a machine similar to the 'hog' used for grinding up waste slabs in sawmills may be used to reduce camphor limbs to the requisite fineness for distillation. Better distilling apparatus can probably be devised. Thermometers may be introduced to determine the heat in the distilling tub, and the furnace may be so arranged as to permit better control and greater economy in fuel. Improvements may be made in the condensing chamber for collecting the gum and oil in such a manner that they may be easily removed.

REFINING.

The first distillation produces only crude camphor gum, the quality and market value of which depend chiefly on its freedom from water, oil, and all impurities. The crude gum is refined before it is placed on the retail market. The refining process commonly consists in mixing with the crude gum about 2 per cent. of its weight of both carbonate of lime and bone-black, and subliming it in closed cast-iron jars at a fixed temperature just below 400° F., the point at which it volatilizes.

This process requires carefully constructed apparatus and very skilful manipulation. It is not likely that it can be carried on advantageously even by large growers. The best refined camphor should be entirely free from water, oil, or any impurity, and should evaporate in time, leaving no residue whatever.

OUTLOOK FOR FUTURE MARKET.

The consumption of camphor in this country, as measured by the importations, has been decreasing during the past ten years, while the price has been increasing.

There has been an increase in importations of refined camphor, due to improved methods of refining and packing in Japan and to changes in the tariff, but this increase has been much more than counterbalanced by the decrease in importations of crude camphor. The decrease may be attributed to the following causes: (1) The exhaustion of the supply of the available camphor trees near the shipping ports; (2) the government restrictions on the trade in camphor in Formosa; (3) government taxes on the exportation of camphor from Formosa; (4) hostilities and wanton destruction of camphor stills by the natives in Formosa; (5) disturbances in the camphor-producing district of China; (6) the China-Japan war; (7) attempts by speculators to corner the market.

These causes have increased the price of camphor, and this in turn has led to the introduction of substitutes. Menthol and other peppermint derivatives or compounds, carbolic acid and its derivatives, naphthalin, formalin, and insect powder are now used for various purposes where camphor was formerly employed. Artificial camphors, nearly equal to that obtained from the camphor tree, have been produced by several different methods. It is therefore apparent that if the production of camphor from the trees is to be carried on with profit in this country, and the industry increased to any considerable extent, the price of camphor must be reduced to compete with the price of substitutes now taking its place.

MANURIAL EXPERIMENTS WITH CACAO IN DOMINICA.

The following summary of the results obtained during the past four years, in connexion with the cacao manurial experiments, carried on at the Dominica Botanic Station by the Hon. Francis Watts, C.M.G., D.Sc., and Mr. Joseph Jones, the Curator, is in continuation of the results published in the last volume of the *West Indian Bulletin* (pp. 258-62). It should be added that this summary has not been specially prepared for the *West Indian Bulletin* but has been extracted from the Annual Report on the Botanic Station. An account of the cacao experiments in the country districts is also published for general information :—

This summary necessarily consists largely of a repetition of much that was said last year, but in bringing the work up to date some useful points present themselves.

In 1900, a plot of cacao, about $1\frac{3}{4}$ acres in extent, was divided into five plots for manurial experiments as follows :—

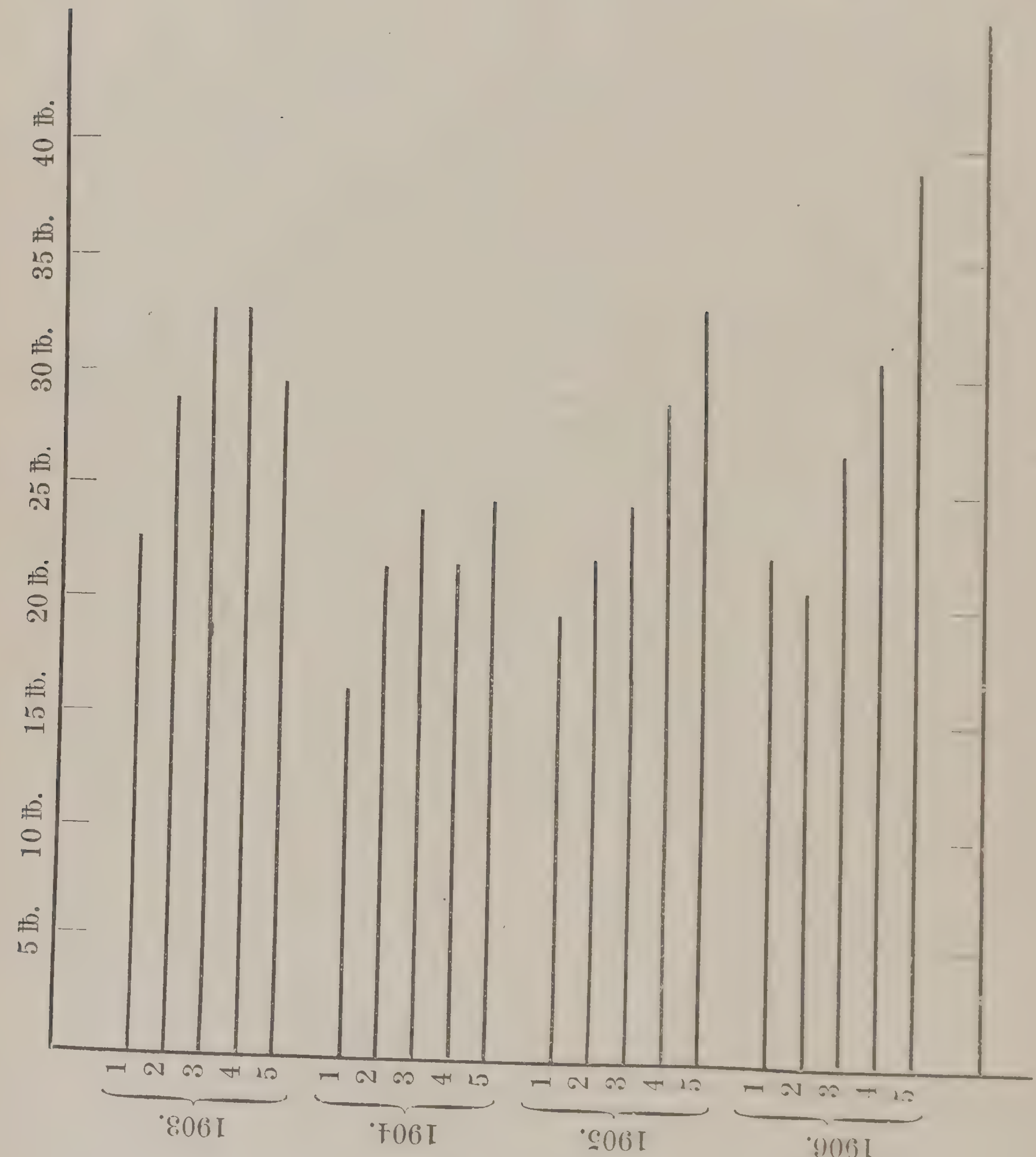
No.	Letter on station plan.	Number of trees per plot.	Manure.
1	C.	34	No manure.
2	A.	37	Basic phosphate, 4 cwt. per acre. Sulphate of potash, $1\frac{1}{2}$ cwt. per acre.
3	B.	40	Dried blood, 4 cwt. per acre.
4	E.	34	Basic phosphate, 4 cwt. per acre. Sulphate of potash, $1\frac{1}{2}$ cwt. per acre. Dried blood, 4 cwt.
5	D.	39	Mulched with grass and leaves.

The cacao trees were about ten years old and planted about 18 feet apart. Chemical manures were applied once in each year, from 1900.

The weight of wet cacao has been recorded for each of the years ended June 30, 1903, 1904, 1905, and 1906. The results are recorded in the table on the next page.

The results, based on the yield per tree, are also given in diagrammatic form for convenient comparison :—

YIELD OF WET CACAO IN POUNDS PER TREE.



YIELD OF WET CACAO IN POUNDS.

No.	Manure.	1903.		1904.		1905.		1906.		Difference on no manure in 1906.	
		Per plot.	Per tree.	Per plot.	Per tree.	Per plot.	Per tree.	Per plot.	Per tree.	Per plot.	Per tree.
1 C.	No manure	759	22·3	548	16·11	673	19·76	748	22·0	...	...
2 A.	Phosphate and potash	1,063	28·7	808	21·83	814	22·00	763	20·62	15	– 1·38
3 B.	Dried blood	1,281	32·2	970	24·25	970	24·25	1,056	26·4	308	4·4
4 E.	Dried blood, phosphate, and potash ...	1,104	32·4	738	21·70	979	28·79	1,040	30·59	292	8·59
5 D.	Mulched with grass	1,145	29·3	962	24·60	1,179	32·79	1,519	38·94	771	6·94

These experiments differ from those conducted with annual or short-period crops in that the effects are cumulative. The experiments are repeated on the same plot of ground and on the same individual trees year after year, and the results of several years have to be taken into account in estimating the effect.

The use of basic phosphate and potash without nitrogenous manure (No. 2. A.) has not proved beneficial, but when a nitrogenous manure, namely, dried blood, is added to the phosphate and potash (No. 4. E.), there is a striking increase in the yield per tree. It appears clear, therefore, that a complete manure, i.e., one containing phosphate, potash, and nitrogen, is most suitable. Unfortuuately, this small series of experiments does not demonstrate what would be the result of not applying potash.

The application of dried blood, which, though chiefly a nitrogenous manure, yet contains phosphate and potash, produces results showing that nitrogenous manures are beneficial, there being a gain of 308 ℔. of wet cacao, or 4·4 ℔. per tree over the no-manure plot.

The most interesting plot is the one mulched with grass and leaves, the sweepings of the lawns at the Botanic Station. In the first period this plot, though giving a greater yield than the no-manure plot, fell far behind the plot receiving dried blood or the plot receiving complete manure, namely, dried blood, phosphate, and potash; in the second year it again exceeded the no-manure plot and also the plot not receiving phosphate and potash (2. A.) and that receiving dried blood with phosphate and potash (4. E.); the yield was practically identical with that from the plot receiving dried blood alone (3. B.). In the third year this plot far surpassed all the others, giving yields 66 per cent. greater than that obtained from the no-manure plot.

For the fourth period (1905), now under review, the result is even more striking, the yield per tree being 38·91 ℔. of wet cacao, against 22 ℔. per tree from the no-manure plot, a gain of 77 per cent. The general appearance of the plot leads one to suppose that a permanent improvement has been effected, the soil is more moist and darker in colour, while the trees have a better surface root development, so that the future history of the plot will be watched with interest.

The yield, obtained from the area of about 1¾ acres covered by these five experiments, is very satisfactory; it amounted to 5,126 ℔. of wet cacao this season, equal to 1,230 ℔. of cured cacao per acre. The return from the plot receiving no manure may be regarded as good, when compared with general yields. While the results in the aggregate show that it is profitable to manure cacao, more particular interest attaches to the plot mulched with grass and leaves.

As 100 ℔. of wet cacao are found to yield 42 ℔. of dry cacao, and as the trees are planted about 18 feet apart, or at the rate of 134 trees per acre, approximate calculations may be made as follows:—

YIELD PER ACRE IN 1906.

Dry Cacao. Pounds per acre.		Grain over no manure in pounds.	Value of increase over no manure (at 6*d*. per lb. of dried cacao).		Cost of manure.		Grain by manuring.	
1.	1,238	...	s.	d.	s.	d.	s.	d.
2.	1,160	78	– 39	0	45	3	– 84	3
3.	1,486	248	+ 124	0	36	0	+ 88	0
4.	1,722	484	+ 242	0	81	3	+ 160	4
5.	2,191	953	+ 476	6	60	0	+ 416	6

The whole area is fairly covered with trees which so shade the ground that there is little or no undergrowth. Such weeds as may occasionally appear are pulled up; owing to the soil being well filled with roots, there has been no attempt at tillage, that is to say, there has been no hoeing nor any attempt to turn over the soil. The leaves falling from the trees form a thin surface covering. The artificial manures are spread broadcast and lightly raked in.

The plot mulched with leaves and grass, the sweepings of the lawns at the Botanic Station, received 4 car baskets of Saman leaves, with which is mixed a proportion of grass, per tree per year. The Saman tree sheds its leaves in May: these are at once collected and applied to the cacao. Mulching is done only once a year.

The material employed consists chiefly of cut grass, the result of mowing the lawns, and the leaves falling from the trees around the lawns, principally Saman trees (*Pithecolobium Saman*).*

* An analysis was made of the sweepings obtained from under the Saman tree with the following result:—

	Per cent.	Per ton (2,240 lb.).
Water	12·62	282·6
*Ash (sulphated)	9·48	212·4
†Organic matter	77·90	1,745·5
	100·00	2,240·0
†Containing nitrogen	2·116	47·4
* ,, phosphoric acid, P_2O_5	0·156	3·5
,, potash, K_2O	0·644	14·3

The mulch is allowed to incorporate itself with the soil by natural agencies: it is not buried or forked into the soil. The thickness of the mulch at any one time, even when freshly applied, rarely exceeds 1 inch.

The successful cultivation of orchard crops, such as cacao, in the tropics demands methods which lead to the conservation of humus. When a plantation is young and the trees occupy but little space, the natural growth of weeds between the trees tends to conserve the humus, owing to the decay on the spot of the weeds after the necessary periodic weedings.

Care is necessary in the control of weeds in young orchards. The trees themselves should be kept free from their encroachments, while the weeds in the intervening spaces should be periodically cut down and spread as a mulch. The successful control of these operations demands knowledge and skill on the part of the manager, more perhaps than in the cases where perfectly clean cultivation is aimed at. Where the rainfall is in any way deficient, it will be preferable to limit the amount of weeds in the intervening spaces and to supplement the mulching by material (grass, bush, etc.) brought from another locality. The point to be aimed at is the increase of the humus, which in the tropics rapidly tends to disappear.

At a certain stage in the development of a cacao field the trees develop until the interlacing branches so shade the ground that no undergrowth of weeds is developed. At this stage, which corresponds with that of the plot under experiment, it becomes necessary to obtain material for mulching from other localities. In Dominica, with its large extent of uncultivated land, there is little difficulty in obtaining adequate supplies of grass and bush; these materials should be fully utilized, when, as the experiment now under discussion fully demonstrates, a large increase in the yield of cacao may be obtained without the use of artificial manures. With such immense supplies of material available for mulching it appears wasteful and unnecessary to purchase artificial manures. Herein probably lies the answer to the question how best to improve our cacao cultivation.

In those places where cacao is so extensively grown that little waste or uncultivated land exists, it is worth while considering whether definite spaces should not be set aside, and, if necessary, cultivated and manured, for the production of material for mulching.

Experience appears to indicate that, following the method here briefly sketched, the texture and tilth of the soil appear to be satisfactorily maintained without any extensive forking or tillage operations: the roots of the cacao trees thus escape the injury incidental to these operations. A prudent planter would, of course, take note of the state of the soil in any particular case and take such steps as prudence and experience dictate.

In brief, orchard cultivation in the tropics appears to depend largely for its success upon the proper understanding of the humus problem.

CACAO CROP AT THE BOTANIC STATION.

The crops of cacao gathered at the station during the past four years are given below. The area under this cultivation is estimated to be 6 acres:—

Year ending June	1903	50 cwt.
,, ,, ,,	1904	44 ,,
,, ,, ,,	1905	52 ,,
,, ,, ,,	1906	56 ,,

During the year ended June 30, 1906, 25 bags of cacao, of 2 cwt. each, were shipped to London. At the end of the crop 1 bag, of 2 cwt., was sold locally. The remaining 4 cwt. are represented by 4,800 cacao pods (nearly 4,000 of these being purchased by planters for seed, the rest being used for the same purpose at the station), and 50 lb. of cured cacao supplied to the Agricultural School.

EXPERIMENT PLOTS IN COUNTRY DISTRICTS.

The crop returns having been carefully kept for several years, it may be of interest to review several of them.

Clark Hall.

On the Clark Hall plot, 1 acre in extent, 60 feet above sea-level, the expenditure for the four years 1903-6 was £16, or at the rate of £4 per acre per annum. During this period, 8,189 lb. of wet cacao were gathered. Taking 100 lb. of wet cacao as yielding 42 lb. of dry or cured cacao, the return of the latter is 3,440 lb. This is at the rate of 860 lb. or $7\frac{1}{2}$ cwt. of cured cacao per acre per year. Taking cacao as netting $4\frac{1}{2}d.$ per lb., at the present low rates, the return is £15 15*s.* per acre, or a gain over the expenditure of those years of £11 15*s.* per acre per year.

The plot is divided into four sections, A, B, C, and D.

A receives an annual dressing of pen manure.

B receives 4 cwt. per acre of basic phosphate annually; in 1902 it also received a dressing of dried blood at the rate of 8 cwt. per acre.

C receives annually 4 cwt. per acre of dried blood.

D, in the first two years, 1900 and 1901, received in each year heavy dressings of basic phosphate at the rate of 8 cwt. per acre.

The returns from the plots have been as follows:—

WET CACAO. POUNDS PER PLOT.

Year.	A.	B.	C.	D.
1902-3	388	459	318	320
1903-4	528	587	442	547
1904-5	847	829	505	644
1905-6	560	458	405	332
Total ...	2,323	2,333	1,670	1,863

From the above the efficiency of pen manure is evident; plot A, for the past two seasons, having given the largest return.

The basic phosphate appears to have been beneficial, plot B having given far larger returns than plot C, with which it may be compared. The effect of the heavy dressings of phosphate, given to plot D, in 1900 and 1901, was evident in the increased return in 1903-4 and 1904-5; this appears to be less marked in 1905-6.

Although these experiments cover but a limited range, they may be taken as indicating the value of pen manure and of phosphatic manures. It is desirable that these experiments should be continued for some years longer, using on plot A pen manure; on plot B basic phosphate; on plot C dried blood, and on plot D no manure, to constitute a control.

POINT MULÂTRE.

The expenditure on the Point Mulâtre plot, 1 acre in extent, 50 feet above sea-level, for a period of four years, 1903-6, was £19 16*s.*, or practically at the rate of £5 per acre per annum. The return of wet cacao was 7,778 ℔., equal to 3,266 ℔. of cured cacao. This is at the rate of 816 ℔. or 7¼ cwt. per year. At 4½*d.* per ℔., this yields £15 6*s.*, or a return of £10 6*s.* per acre per year. This plot does not contain an acre of bearing cacao. During the four years a portion was being established in young cacao. This plot was intended rather to demonstrate cultural methods than to ascertain the effect of manures.

MOORE PARK.

At the Moore Park cacao plot, 1 acre, elevation above sea-level 750 feet, the expenditure during 1903-6 was £13, or £3 5*s.* per acre per year. The return of wet cacao was 5,821 ℔., or equal to 2,440 ℔. of cured cacao. The rate per acre is 611 ℔. or

$5\frac{1}{2}$ cwt. At $4\frac{1}{2}d.$ per lb., the return is £11 9*s.*, showing a balance of £8 4*s.* per acre per annum. The return from this plot is very good for Dominica, when the elevation is considered.

The Moore Park experiment consists of two plots each of $\frac{1}{2}$ acre. During the first two years, 1900 and 1901, a dressing of 4 cwt. per acre of basic phosphate was applied each year to both of the plots. During this time the trees, which were about fifteen years old, and not in very good order, were being pruned and thinned out. In 1902 no manure was given to plot A, but an application of 4 cwt. per acre of dried blood was given to B. From this time onward 4 cwt. per acre of basic phosphate has been given to A, and 4 cwt. per acre of dried blood to B. The plots should now continue to receive this treatment annually so as to afford a comparison between the effects of phosphate and of dried blood. The general condition of the plots has been maintained by bedding in the weeds, leaves, etc.

The yield of wet cacao from the two plots has been as follows :—

WET CACAO. POUNDS PER PLOT.

Year.	A.	B.
1902-3	534	512
1903-4	860	854
1904-5	840	885
1905-6	711	625
Total ...	2,945	2,876

In the early years the returns from the two plots were remarkably similar—both plots, it will be remembered, were receiving the same treatment. The results of 1905-6 appear to point to some gain from the use of phosphate in contrast with dried blood. The results to be obtained in the future should afford useful information.

PICARD.

The Picard cacao plot was started at the close of 1900 on land that was considered unsuitable for cacao. It is 1 acre in extent, divided into four sections for manurial treatment. The land was cleared of bush and roots, and cacao planted at 13 feet apart. Bananas and tannias supplied the necessary shade. Special manures were applied each year. The amount expended on the plot during five and a half years was £29 2*s.* The return during the fifth year was $\frac{1}{2}$ cwt. of cured cacao. The trees are now of a large size and very healthy. This is

a specially interesting plot and should be maintained for a few years longer in order to show the expenditure on, and return from, a cacao plot on coast lands in Dominica for the first decade of its existence.

(a.) Government Plots.

In the early stages the area comprising all four of the Government plots at Picard was manured with pen manure and dried blood, the object being to give such general treatment as would best assist the establishment of cacao in a locality then regarded as doubtful. In 1903 the plots were differentiated for manurial experiments: from this time onward the treatment was as follows:—

A received pen manure.

B received 2 cwt. per acre of sulphate of ammonia.

C received 4 cwt. per acre of basic phosphate.

D received 4 cwt. per acre of dried blood.

It has been found that the soil of the southern half of plot D is very thin and gravelly; this plot has therefore been sub-divided and the poorer (southern) half has had applications of pen manure in 1905 in order to attempt to restore fertility.

The individual trees on the four plots were carefully measured in January 1906 by Mr. Sowray. The following is a summary of the results:—

Plot.	Average height.	Average girth.
A. Pen manure ...	9·55 feet	7·8 inches
C. Basic phosphate ...	9·25 ,,	8·0 ,,
D. Dried blood	8·55 ,,	7·15 ,,
B. Sulphate of ammonia	8·95 ,,	6·1 ,,

The trees are now in bearing. During last crop 1905-6 the first pickings were made as follows:—

A. Pen manure	319	pods per plot.
B. Sulphate of ammonia ...	235	,, ,, ,,
C. Basic phosphate... ...	390	,, ,, ,,
D. Dried blood	133	,, ,, ,,

The foregoing results suggest that phosphatic manures are beneficial to cacao, as is to be expected from the very small amount of phosphate present in most of the soils of Dominica. From the poverty of the soil in one portion the dried blood plot (D) is not fairly comparable.

The conclusions drawn from observations made on these plots is that manures encourage the general growth of the trees but, to some extent, retard the period of bearing. It appears desirable to employ manures in order to obtain well-formed healthy trees even at the expense of some delay in reaping a crop.

During the progress of the experiments there has been considerable improvement in the appearance of the soil, which has doubtless increased in fertility. The weeds, which naturally spring up amongst young cacao, have been carefully conserved, being either spread as a mulch, or lightly turned in after being periodically cut down. (See *West Indian Bulletin*, Vol. V, p. 287 --'Manurial Value of Weeds in Cacao and Lime Orchards.')

In view of the fact that the lands upon which these experiments were conducted were regarded as of doubtful value for cacao cultivation when the experiments were laid out, it is interesting and important to note that the surrounding fields have now been planted in cacao and cultivated on lines based on the use of artificial manures coupled with the careful and intelligent use of weeds as manure. The results are very promising; the character of the soil has improved in a marked degree, and the young trees look flourishing. These doubtfully regarded lands promise to be among the most satisfactory for cacao, a result of some importance.

(b.) *Larger Manurial Experiments at Picard.*

Mr. Sowray, the representative of Messrs. Rowntree & Co., has laid out a more extensive series of manurial experiments with cacao. These are conducted at Messrs. Rowntree's expense, the Department of Agriculture giving any advice which may be desired. These experiments being at present in a very early stage, it is not yet desirable to attempt to draw definite conclusions from them: it is, however, important that the results should be placed on record for reference.

Each plot contains sixty-four trees and measures $\frac{1}{4}$ acre each plot is separated from its neighbour by two rows of cacao trees: three rows run through the middle of the plots, separating plots 3 and 6 from 7 and 10. In addition to noting the number of pods gathered from each of the plots, Mr. Sowray has placed on record the number of pods gathered from the intervening rows. The results are as follows:—

			Pods per plot in 1905-6.
No. 1.	Bone meal, 1 cwt. per acre		565
	2 intervening rows	74 pods	
No. 2.	Basic phosphate, 1 cwt. per acre ...		439
	2 intervening rows	77 ,,	
No. 3.	Sulphate of potash, $\frac{1}{2}$ cwt. per acre...		593
	3 intervening rows	290 ,,	
	2 rows between the six sections ..	428 ,,	
No. 4.	Basic phosphate and sulphate of ammonia, each 1 cwt. per acre ...		787
	2 intervening rows	331 ,,	
No. 5.	Sulphate of potash, $\frac{1}{2}$ cwt.; sulphate of ammonia, 1 cwt. per acre ...		557
	2 intervening rows	151 ,,	
No. 6.	Sulphate of potash, $\frac{1}{2}$ cwt.; basic phosphate, 1 cwt. per acre		405
	3 intervening rows	30 ,,	

			Pods per plot in 1905-6.
No. 7.	Pen manure, 2 baskets per tree ...		626
	2 intervening rows	105 pods.	
No. 8.	Dried blood, 2 cwt. per acre ...		635
	2 intervening rows	172 ,,	
No. 9.	Compost		255
	3 intervening rows	142 ,,	
	2 rows between the six sections ...	647 ,,	
No. 10.	Sulphate of ammonia, 1 cwt. per acre		279
	2 intervening rows	61 ,,	
No. 11.	Sulphate of ammonia, 1 cwt.; basic phosphate, 1 cwt.; and sulphate of potash, ½ cwt. per acre		646
	2 intervening rows	4 ,,	
No. 12.	No manure		270
	2 intervening rows	52 ,,	

These experiments should be continued for a series of years, when very interesting results may be expected.

RIVERSDALE.

The Riversdale cacao plot was started in January 1903, on virgin forest land 9 miles from the coast. The expenditure to March 31, 1906, was £19 2*s.* 10*d.* It would be interesting to continue this plot for several years in order to compare the cost of establishing an acre of cacao on virgin land without manure and on an acre of cacao on coast land with manure. The crop returns on two such plots would be instructive and tend to clear up several obscure points.

The returns from cacao experiment plots at various estates and at the Botanic Station show that cacao can, with good treatment, be made to bear abundantly in Dominica. The best method of quickly increasing the output of cacao would be by carrying out a system of intensive cultivation. It is clear that, given a supply of plant-food, old cacao can be made to yield good crops.

In cacao growing in the interior of Dominica, the experiences of early settlers have shown that drainage is the most important point in connexion with the cultivation of land in these wet districts. It is evident that an efficient drainage system should be in existence before planting is done. This also applies to plantations on the windward coast. The planters on the leeward coast, owing to lighter rainfall and more open character of the soil, are, to a very great extent, relieved of this heavy charge.

CHILLIES OR CAPSICUMS.

By W. R. BUTTENSHAW, M.A., B.Sc.,

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Chillies are the fruits of plants of the genus *Capsicum*, belonging to the natural order *Solonaceae*. These fruits have a hot, pungent property, due to the presence of an alkaloid known as capricine, and it is in allusion to this property that the genus has received its name, which is derived from a Greek word, *Kapto*, signifying 'to bite.' The economic value of these fruits has long been known. They are also used medicinally.

The members of this genus, which sometimes receive the name of 'peppers,' must not be confused with the real peppers, which belong to the genus *Piperaceae*, and which are, for the most part, climbing shrubs. The capsicums are shrubby or herbaceous plants, usually growing to a height of 2 or 3 feet. The fruit is a juiceless berry or pod with many seeds, and is very variable in shape.

The members of the genus (of which there is a large number of species) are chiefly native to tropical America. Much confusion exists as to the nomenclature of these plants, especially among the multitude of cultivated forms. In a paper on the genus, published in the ninth report of the Missouri Botanical Garden, Mr. H. C. Irish has separated them into two species—*C. annuum* and *C. frutescens*—preserving the well-fixed types as botanical varieties. *C. annuum* 'furnishes all the leading commercial varieties now in cultivation. In temperate countries they are treated as annuals, while in tropical countries some varieties are biennial or perennial.' Of *C. frutescens* he says: 'As the fruit of this species does not ripen freely except in tropical and subtropical latitudes, it is not grown commercially in the north.'

The difficulty in placing the large number of cultivated varieties is due to the strong tendency of the plants of this genus to variation. Individuals are greatly influenced by cross-fertilization when more than one variety are grown. In the West Indies the best varieties rapidly deteriorate, becoming, even after a very few years, nothing better than 'bird peppers.'

Opinions appear to differ as to which species is the source of cayenne pepper. Apparently *Capsicum annuum*, *C. frutescens*, and *C. minimum* are all used.

C. annuum is known as the 'common annual pepper' or as 'red pepper,' also as 'guinea pepper.' The names 'spur pepper,' 'goat pepper,' and 'shrubby pepper' are apparently all applied to *C. frutescens*; 'bonnet pepper' is *C. tetragonum*, 'bird peper' *C. baccatum*, and 'bird's-eye pepper' *C. minimum*.

USES OF CAPSICUMS.

Capsicums are principally used as a condiment; they are also utilized in medicine. According to Spons' *Encyclopaedia of Manufactures and Raw Materials*, 'the fruit of more than

one species of *Capsicum* possesses a pungency which renders it useful as a local stimulant, in the form of gargle and liniment: it is also administered to assist digestion. Its principal application, however, is as a condiment.

'Nepaul capsicums, which have an odour and flavour of orris-root, are the most esteemed as a condiment.'

The term 'chillies' is usually applied to the dried ripe or unripe fruits.

Cayenne pepper consists 'mainly of the fruit of the small pungent varieties reduced to a fine powder.' It is made as follows: The ripe fruits are first dried and ground: then they are mixed with wheat flour and made into cakes with yeast. These cakes are baked till hard, ground, and sifted.

The *Bulletin of the Botanical Department*, Jamaica (1899. p. 69) reproduced from the *Pharmaceutical Journal* the following note by Mr. E. M. Holmes:—

'During the last three or four years there has been in commerce a very bright-red variety of *Capsicum minimum*, Roxb. (*C. fastigiatum*, Bl.) said to be imported from Japan. In consequence of its clean, bright, and attractive appearance, it has commanded a higher price than other varieties. Mr. J. C. Umney has recently directed my attention to the fact that this variety is less pungent than the Sierra Leone and Zanzibar varieties, although far superior to them in colour. On further inquiry I find that this fact is well known to drug and spice brokers. Mr. Umney points out that when an alcoholic tincture of the Japanese and Zanzibar varieties is respectively diluted with about 14 parts of water, the former gives a much clearer solution than the latter, indicating less oily matter. All the bright-red cayenne pepper until recently in commerce is said to have been imported from Natal in that state. The entire pod pepper imported from Natal is a variety of *Capsicum annuum*, much larger than the chillies, and of a dark-red colour and very pungent, whereas the powdered Japanese and Natal cayenne peppers, placed side by side, are indistinguishable in point of colour. The other principal varieties of chillies at present in English commerce are, I am informed, those of Sierra Leone and Zanzibar, the former being of a yellowish-red tint, and the latter of a dull, dark-red, and often of inferior quality, containing badly-dried fruits, stalks, and foreign matter: but both are more pungent than the Japanese kind. The latter is, however, quite pungent enough for most people, although perhaps unsuitable, by reason of its lesser pungency, for medicinal purposes, as an outward application, etc. I am indebted to Mr. Young, of the firm of Messrs. Dalton & Young, for information concerning the different commercial varieties and for specimens illustrating them. My object in directing attention to these commercial varieties is to point out to students and to retail chemists that there are often differences in the qualities and appearance of the same drug, which are worthy of careful observation, not only from a scientific, but also from a commercial point of view. Nepaul cayenne pepper is made from a small variety of *Capsicum annuum*, and is

remarkable for its violet odour. Neither this kind nor the Zanzibar gives a red, but a brownish, powder.'

PRODUCTION OF CAPSICUMS.

In the early seventies the capsicum market was chiefly supplied by Sierra Leone, Natal, and India. Now, supplies are largely obtained from Zanzibar and British East Africa. With regard to the production of chillies, Simmonds says in his *Tropical Agriculture* :—

'There is an enormous consumption of chillies in India, as both rich and poor daily use them, and they form an important ingredient in the curries and chutneys in general use; when ground into a paste between two stones, with a little mustard, lard, oil, ginger, and salt, this forms the only seasoning which the millions of poor in the East can obtain to flavour their insipid rice.

'In 1870 there were more than 70,000 acres under culture with capsicums in the Madras presidency, the largest portion being in Kistna. The exports from Madras in the four years ending 1855 were 81,042 cwt. Bombay imported, in 1873, 5,567 cwt., principally from the Madras presidency, and exported 3,323 cwt. In 1871 Singapore imported 1,071 cwt., chiefly from Pinang and Pegu. The spice is largely consumed by the Chinese. Four hundred and nine and a half piculs of dried chillies were shipped from Chefoo in 1871 to other Chinese ports. *C. annuum* is extensively cultivated in Bengal; there is a variety growing in Nepaul (*C. Nepalensis*) the taste of which is far more pungent and acrid than any of the preceding named species.

'In Natal the capsicum plant grows in perfection, and yields a profit to a limited number of growers. The export of cayenne pepper has averaged, for ten years, £600 per annum, exclusive of inland and local consumption. But the export has been declining for some years. The shipments of Cayenne in 1880 were only 17,277 lb.; but in 1883, 187 cwt., valued at £510.'

CAPSICUMS IN ZANZIBAR.

The cultivation of chillies is an industry of some importance in the island of Zanzibar. The exports during the past ten years have been of the annual value of about £8,000. The figures are as follows: 1897, £7,155; 1898, £3,899; 1899, 412,011 lb. (value, £5,419); 1900, 810,693 lb. (value, £12,130); 1901, 910,567 lb. (value £11,201); 1902, 554,238 lb. (value £7,633); 1903, 516,428 lb. (value £7,116); 1904, 477,453 lb. (value, £8,305).

According to information contained in the annual *Consular Reports*, the cultivation of chillies is practically confined to the eastern portion of Zanzibar, being carried on by the 'Wahadimu'—the original inhabitants. As the soil seems particularly suitable to this crop, it appears to be unfortunate that greater attention is not paid to the cultivation of chillies. As it is, very little trouble is taken in preparing the product for the market, with the consequence that Zanzibar chillies have fetched the poorest prices (viz., only 30s. to 31s. per cwt.) of any on the

market. The growers frequently allow the ripe pods to drop to the ground, where they may lie for some days before being collected. Further, no attempt is made to free the pods of stalks, dried leaves, or earth which may be adhering to them. If the pods were stalked and the dirt removed, it is probable that the Zanzibar product would realize some 15*s*. per cwt. more. This was shown by a shipment made by the Agricultural Department from an experiment plot of about 3 acres; the sample was reported to be far superior to the ordinary Zanzibar product.

The following extracts from the report of the Agricultural Department for 1901 are of interest: –

'The trees are planted by the people, but they also grow from seed that has been self-sown, or that has been scattered by birds. When the chillie season is over, the natives prune the bushes down to within a foot of the ground, which promotes young growth the following year. The quality of Zanzibar chillies has deteriorated in recent years, and the price has, in consequence, fallen. . . . Chillies are the fruit of the plant and are supported on peduncles of about an inch in length. The peduncles generally spring in pairs from a single node. The nodes are often close together, and when this is so four to six chillies will all grow in a clump and can be plucked together. But to separate them from the peduncles or stalks on the tree the pods should be plucked singly. The operation requires a wrench, which cannot be properly executed when several pods are plucked together. It requires an expert woman to make a living picking chillies, and with a low market greater expedition must be used if a day's wage is to be earned. Hence the chillies, instead of being picked singly, are bunched off in handfuls, stalks and all. This explains the presence of stalks in samples. Chillies pack light when dry. . . .

'The pickers and small traders are often too poor or too improvident to provide drying mats, but spread the pods on the ground. Unless chillies are thoroughly dry they discolour when kept. At Dunga we have to turn out our bulk now and then and expose it afresh to the sun. If sweating and heating take place in our dry godowns, and with chillies that have been well dried, it is easy to imagine what takes place in the damp leaky huts of the Wahadimu, especially in wet years, like the last three have been.'

In the *Kew Bulletin* (1892, p. 88) the following information was given respecting the cultivation of chillies in Zanzibar: —

'The small red peppers or chillies are largely grown in the more dry or rocky part of the island, where the upheaval coral presents a honey-combed surface, that favours the accumulation of rich soil in the crevices. The pods are picked when ripe, sundried and packed in mat bags made of the split frond of the *Hyphaene* palm for shipment. This is an industry that has sprung up within the last thirty years.'

Zanzibar chillies, as they appear in the market in a dry state, are small, red, thin, carrot-shaped fruits about an inch in length.

The following further particulars are contained in a report on the spice and other cultivations of Zanzibar and Pemba (Foreign Office Report, 1892, Miscellaneous Series, No. 226):—

'The pepper plant growing in the island is *Capsicum minimum*, usually termed the "shrubby capsicum," and producing the bird's eye chillies forming the basis of cayenne pepper. This is to be found in a small degree in every shamba, but the principal source from which the annual exports are derived is the eastern side of Zanzibar, and the cultivation here is chiefly in the hands of the Wahadimu people.

'Judging from observations made during my brief visit to this portion of the island, east of Dunga, the chillie cultivation struck me as being of a very scattered nature, generally small isolated patches from ½ acre to 1 or 2 acres in extent, and combined with tobacco, tomato, pumpkins, etc. I regret my inability to quote the annual total exports, but I believe they are large, and an undoubted source of revenue. As the chillie is, as yet, the only product of any value grown in this less favoured portion of the island, I consider that this cultivation could be extended, and that a little fostering care might be productive of much advantage. It is a cultivation easily carried on, and calling for no special trouble or skill, and the returns are certain and profitable. At present the people are so blind to their own interests as purposely to depreciate the value of this product. I understand that, through fear of possible shortage by theft on the way down, owners actually damp the chillies before despatching, and it is often necessary, on their reaching the Government Customs godowns, to dry them as quickly as is possible as the only chance of saving them.

'Another variety of pepper (*Capsicum annuum*) bearing a larger red and yellow pod is also cultivated, but the produce from this is all consumed locally.'

It may also be mentioned that there has been a considerable extension of late years in the cultivation of capsicums in Uganda. The kind grown is the small Zanzibar variety. The exports from the colony in the year 1904-5 were of the value of £4,383.

In British Central Africa, also, it is reported that the cultivation of chillies is being extended, as their export has proved profitable.

CAPSICUMS IN THE WEST INDIES.

At several of the West Indian Botanic Stations capsicums have been grown in the experiment plots with more or less satisfactory results.

At the Antigua Botanic Station a small area, $\frac{1}{10}$ acre in extent, was sown with Natal peppers in August 1904. Reaping commenced in November and continued up to the end of the following March, the yield being 113¾ lb. as reaped.

The best results have been obtained at the Experiment Station in Nevis. Two kinds were tried, viz., the ordinary red and the yellow Nepaul. The former began to bear earlier, viz., at four and a half months from planting. The following extract

from the *Agricultural News* (Vol. IV, p. 280) deals with the sale of the crop and is of interest as showing the possibilities of the cultivation of capsicums as a useful minor industry :—

'A shipment of peppers from the Nevis Experiment Station, recently forwarded to London by the Imperial Commissioner of Agriculture, has been disposed of at very good prices.

'The consignment consisted of 64 ℔. net weight of yellow Nepaul peppers and 53 ℔. of ordinary red chillies.

'The former realized the very high price of 51*s*. per cwt. This, however, is not, according to the brokers' report, to be attributed to their intrinsic value, but to their being in a very small lot and to competition between two bidders who particularly wanted them. We should not think it safe to expect more than 30*s*. per cwt. for any quantity.

'The red chillies realized 26*s*. per cwt. These were reported slightly mouldy and would appear not to have been properly dried before shipment.'

A further shipment (of 1 barrel) was made in May last with the result that the peppers sold 'at the exceptionally high price of 80*s*. per cwt.' The following note appeared in the *Agricultural News* (Vol. V, p. 232) in regard to this shipment :—

'Messrs. Lewis & Peat, of Mincing Lane, London, to whom the shipment was made, have reported as follows :—

'" We have the pleasure to enclose contract for a little lot of capsicums shipped from St. Kitt's, which we have sold at the exceptionally high price of 80*s*. per cwt. We could not, of course, rely on anything near this figure for any quantity. The average value would be not more than about 40*s*. per cwt. If the quality can be kept up to the small trial shipment, we think this value might be relied upon. Of course, it must be borne in mind that there is only a very limited demand for this description of chillies." '

MARKET FOR CAPSICUMS.

In August last the Secretary of the West India Committee wrote to the Imperial Commissioner of Agriculture that, as one of the results of the Indian and Colonial Exhibition at the Crystal Palace, he had received inquiries as to whether capsicums could be shipped in bulk from the West Indies.

In his monthly report on the London drug and spice market for September 1905 (see *Agricultural News*, Vol. IV, p. 351), Mr. J. R. Jackson, A.L.S., made the following reference to trade in capsicums :—

'On the 6th., fine Nyassaland, 37*s*.; large Japan, 24*s*. per cwt. On the 13th., good bright red, East Coast of Africa, 33*s*. 6*d*. On the 20th., Mombasa chillies were bought in at from 28*s*. to 30*s*.; some fine bright small Mombasa capsicum chillies, without stalks, 62*s*.; fine red Japanese chillies, 34*s*. On the 27th., good bright Zanzibar and Mombasa, 28*s*. to 30*s*.

CULTIVATION OF CAPSICUMS.

The cultivation of capsicums is quite simple, as they require merely the ordinary care that should be given to all

garden crops. On this account their cultivation would seem to be particularly suitable for peasant proprietors. Capsicums are apparently not susceptible to insect attacks, though there are two fungoid pests which sometimes cause trouble. These are known as 'pink anthracnose' (*Glœosporium piperatum*) and 'dark anthracnose' (*Colletotrichum nigrum*).

The land which is to be planted with capsicums should be well prepared beforehand. It should be brought into good tilth by ploughing or forking. If the soil be poor, manure may be applied while the land is being prepared. Fresh manure, applied after the plants have been set out, is apt to produce excessive leaf growth and poor yields of fruits.

The seed should not be broadcasted but should be sown in a well-prepared nursery bed, and covered to a depth of about ½ inch with loose sandy soil. The seeds take from twelve to twenty days to germinate. The seedlings should be transplanted as soon as they are large enough to handle, say, about 4 inches high. They should be set out in rows so that the land can be properly weeded and cultivated. The rows should be about 2 feet apart, and the seedlings be set about the same distance apart in the rows.

Watering may be necessary should the weather be dry, but should cease when the fruits begin to ripen. The cultivation would easily lend itself to irrigation if necessary.

It is desirable that the plants should be moulded up as soon as they are well established. Frequent weeding will be necessary; the soil between the rows can be worked with a cultivator, or hoed.

The pods will begin to ripen in about four months from planting, and the ripening will continue for some time. The plants should be gone through once a week, and all the fruits that are fully ripe gathered. They should not be allowed to fall to the ground. Dry weather should, if possible, be chosen for picking. Any fruits having breaks or blemishes should be discarded, as they would decay before drying properly.

The next operation is the drying and curing of the fruits. This is probably the most important point, for whether the grower will get a good price for his product will depend upon the proper curing. If chillies are stored damp, they will soon be quite spoiled. Before storing, therefore, they should be spread out in the sun to dry. They must be handled carefully to avoid breaking the skin. As has already been mentioned, the Zanzibar product has fetched the lowest prices on account of its dirty condition. The chillies, having been dried on the bare ground, were dirty. It is also necessary that the fruits should be carefully stalked before shipment.

In reference to the matter of drying capsicums, it may be of interest to quote from the last Annual Report of the Agricultural Instructor for Nevis. Mr. Hollings says:—

'It is essential, in order to preserve their bright colour, that the peppers should not be picked till thoroughly ripe, and then dried as rapidly as possible. Drying is easily accomplished in the sun and wind in trays with fine wire-netting

bottoms, so as to allow the air to circulate freely. These trays should fit into a rack one above the other but with a good air space between them; the trays can then easily be put out in the sun, and if rain threatens, run into their rack under cover instantly. Peppers lose roughly about 70 per cent. of their picked weight in drying (about 2 per cent. are stalks which have to be removed before shipping, although they should always be picked with them on); some 6 to 7 per cent. will, with the most careful picking and drying, be slightly discoloured and had better be rejected from shipment; they will be quite good for seed. The remaining 23 or 24 per cent. are fit for the market.

'Even such pungent things as peppers are not free from the attacks of worms. The resulting crop of this season was carefully selected and packed in barrels for shipment. When, after some unavoidable delay, the barrels were opened and again examined, they were found to be badly attacked by these worms and the envelope or skin nearly destroyed.'

Sometimes chillies are strung. This method is described by a writer in the *California Cultivator* as follows :—

'The common method is to cut strings of strong, smooth twine 8½ feet long. Draw this through a needle about 10 inches long, which is often made of a bicycle spoke. Peppers having any breaks or blemishes must be thrown away, as they would decay before drying properly. Of course, where an evaporator is used, these can be saved. After the strings are full and tied they are hung on nails driven into a rough pole or other framework standing about 6 feet from the ground, and left until dry; or if shelter is available, they may be moved before becoming fully dry and hung closely together under such shelter, but where there is a free circulation of air.

'Many growers prefer evaporating instead of drying. The evaporators used are of various designs and sizes, but they should be large enough, when the peppers are dried on strings, to hold not less than 500 strings. The usual plan is to have a furnace with several turns of 8-inch to 10-inch pipe in the basement, the peppers being placed in the second story over a very open floor and with good ventilation. The temperature must be kept at 110° F., and in this way the house can be refilled about every four days.'

The Queensland *Agricultural Journal* gives advice on preserving chillies as follows :—

'Another, and a good plan if the chillies are to be exported, is one which we know by experience to be good, as we have kept them from twelve months without their changing colour or strength. Make a fairly strong brine. Fill a stone jar or a keg with the chillies, and pour the cold brine over them, filling the vessel to the top. Bung down closely. In two or three months, or even after a longer interval, either strain the brine or make fresh, carefully washing out the vessel. They will keep fresh for a long period.'

In regard to the yield of capsicums, the Californian writer, referred to above, states that 1,250 lb. per acre is considered to be a paying crop, but that, under specially favourable conditions, double that quantity may be obtained.

The yield of capsicums from the $\frac{1}{10}$-acre plot at the Nevis Experiment Station was 365 lb. from the first picking and 183 lb. from the second, or a total of 548 lb.

An acre will be tried this year on at least two estates in Nevis to test the commercial value of capsicums on an estate scale.

CULTIVATION OF BROOM CORN.

Considerable interest attaches to the experiments that have been carried on in Antigua, Montserrat, and British Guiana in the cultivation of the broom corn (*Andropogon Sorghum*, var. *technicus*. The results show that good marketable brush can be grown in these islands. It is possible that these experiments may lead to the establishment of a small industry. It would appear that Canada might offer a suitable market for the brush, while the local demand for brooms and hand-brushes might be met by a local-made article.

In Antigua, recently, classes of instruction have been held at the Botanic Station, at which lessons were given in broom making. There are signs that the cultivation of broom corn will be taken up by small growers in Montserrat.

It may therefore be useful to publish a few notes on the cultivation of broom corn, dealing more particularly with the processes connected with the harvesting and curing. These notes have been compiled from Bulletin No. 67 of the Louisiana Agricultural Experiment Station, 'Broom Corn; how to grow and cure it,' by W. R. Dodson; articles in the Queensland *Agricultural Journal* by Daniel Jones, and reports in the New South Wales *Agricultural Gazette* by H. V. Jackson.

VARIETIES.

With regard to the different varieties of the broom corn, Dodge (*Useful Fibre Plants*) says: 'The chief economic difference between broom corn and other varieties of sorghum consists in the greater length, strength, and straightness of the fine stems composing the head, or panicle, and supporting the seeds. The longer, straighter, and tougher these stems or straws, and the greener their colour after curing, the higher the price the product commands. The different varieties of broom corn afford dissimilar products. The Dwarf variety produces the short brush used in the manufacture of small brooms and whisks. It is somewhat difficult to harvest and is cultivated only to a limited extent. Of the large varieties the Evergreen, known also as the Missouri or Tennessee Evergreen, has given

general satisfaction. The Mohawk is regarded as earlier, but as affording a smaller yield. There is some advantage in planting more than one variety and at several different dates so as to extend, through a long season, the season of harvesting.'

CULTIVATION.

The cultivation of broom corn being so similar to that of Guinea corn (a closely related plant), it is scarcely necessary to deal at length with this part of the subject. It may be generally stated that the soil and climatic conditions which favour the growth of Guinea corn will be suitable also for the broom corn.

As this plant does not withstand excessive moisture, a well-drained soil is desirable. The importance of getting the soil into a good state of tilth before sowing the seed is insisted upon by all writers on the subject.

The amount of seed required to the acre is from 6 lb. to 8 lb. The seed is usually sown by hand; but as this is a tedious and somewhat unsatisfactory process, the use of some form of sower is an advantage. Drills should be made 3 to 3½ feet apart, and the seed sown 4 to 5 inches deep. The plants can afterwards be thinned out so that they stand three or four to the foot.

The best distances at which to plant broom corn can really be decided only by actual experience. If too much space is allowed, the plants grow very luxuriantly, producing coarse and unmarketable brush. On the other hand, if the plants are crowded, the brush becomes fine and weak.

Seed is sometimes sown in hills, 15 to 20 inches apart in the drills, leaving six to ten stalks to each hill.

As broom corn is rather long in germinating, and the growth in the early stages is slow, weeds grow apace and frequent weeding is necessary. This can best be carried out with a Planet Junior plough.

BENDING.

The object of this operation is to avoid crooked brush, the presence of which in a sample will always cause a depreciation in value.

It often happens that, on account of the weight of the seed or the tenacity of the sheath, the immature heads become contorted at the base; this is counteracted by bending. The bending has to be carried out before the panicles have quite matured; it will therefore be necessary to go over the field every few days. If properly carried out, bending will not interfere with the maturing of the head and will have the effect of straightening out the fibre. Whenever a head is seen turning down, the stalk should be bent in the same direction as that in which the head appears to be inclined to go. This will cause the head to straighten out. The details of the operation are described in the Queensland *Agricultural Journal* (September 1899) as follows :—

'The process of bending is accomplished by the workman moving down between two drills and gripping the stalk between finger and thumb, giving it a very firm pinch so as not to snap off the broom-head. Then, with a deft motion of the hand, he turns the stalk down. . . . In bending it must be remembered that a clear uninjured stalk of about 6 inches in length is required. The grower will, by experience, find how far this operation of bending is necessary. In most instances it will be found that a considerable number of the stalks will need no attention; hence in such a case, the grower can pass over his crop very quickly.'

CUTTING.

To carry out the harvesting to the best advantage good judgement will be necessary. It is desirable to select dry weather. The time at which the corn is to be cut will depend largely upon the weather, but also upon the particular colour that is required. Some manufacturers prefer brush with a greenish tinge, as the fibre is then tougher. To obtain this, the reaping is done soon after the so-called blossoms (i.e., anthers) have fallen, when the seeds are still soft and milky. Other growers wait until the seeds are mature, for they then obtain a by-product of considerable value in feeding stock. It appears, however, that the ripening of the seed causes a weakening of the fibre.

For cutting nothing better is required than a good strong pruning knife. One of the most essential points is that a stalk of 6 to 8 inches in length is left.

The further handling of the crop is much simplified if tops and butts are laid one way as they are cut off.

When the corn has grown high, say, 12 to 15 feet, it will be advisable to send a boy along in advance to bend the stalks, with a view to making the heads more easily accessible. As celerity is, at this stage, of considerable importance, any unnecessary delay must be avoided. The usual practice is to bend the stalks of two rows towards one another, so that the bent ends support each other in a more or less horizontal position.

In the case of cutting immature corn it becomes necessary to avoid making big heaps of brush; this may sweat and cause heating, resulting in discoloration.

DRYING AND CURING.

The practice to be adopted in the case of the curing and cleaning of the brush will depend upon whether it has been harvested in the immature state, or whether the seeds have been allowed to form. Some growers prefer to strip the brush while it is still green. The fibre from immature brush is more easily cured and cured in a better condition. This practice has, however, the disadvantage that the grower loses the seed, which would be useful for stock feeding. Further, for treating immature brush some form of saw-tooth, cylinder scraper will be required for cleaning.

The drying can be done in the sun, all necessary precautions being taken to prevent the brush from getting wet, as it is readily discoloured by rain or dew. Drying in the sun has, however, a tendency to bleach the brush and turn it yellow.

The best results are usually obtained by drying in the shade. The brush is left in the sun for a few hours and then removed to a shed fitted with racks, arranged in tiers one above the other. The brush is spread on these 2 or 3 inches thick; the spaces between the racks allow of a free circulation of air and the curing will be rapid. Care must be taken to turn the brush every day.

For the removal of the seed various contrivances are employed; they vary from such primitive forms as the curry comb to special mechanical 'seeders.' A small crop could be easily seeded with a wooden comb made by sawing teeth in the end of a board. The seeds are removed by drawing the brush several times through this comb. As already suggested, an ordinary curry comb will also do the work.

In dealing with a large crop, it will be necessary to have a special machine known as a 'seeder,' driven by hand-, steam-, or wind-power. The construction of a simple but efficient machine is described by W. R. Dodson, in Bulletin No. 67 of the Louisiana Agricultural Experiment Station, as follows:—

'A very efficient seeder may be made by driving nails into a cylinder of wood, 12 to 15 inches in diameter, 18 to 20 inches long, and supplied with a central axle, mounted like a grindstone. A gearing of cogwheels, to increase the speed of the cylinder, is almost essential and can be had at a very small cost. When the cylinder is rapidly revolving, the brushes are held so that the projecting nails or teeth will strike the brush and knock the seeds off.'

GRADING AND BALING.

As soon as the brush is dry it should be graded into different classes according to colour, length, and fineness. All crooked or broken brush should be discarded. It is particularly desirable that the different lengths should be sorted out and kept distinct.

On this important matter of grading Mr. J. Russell Murray, of Montreal, writing to the Imperial Commissioner of Agriculture, says:—

'There are various grades of the product: The small dwarf, which is used for hand-brushes; a second grade, which is used for covering the brooms, and a third and coarser grade, which is used for making up the body of the brush. The prices for these grades vary considerably. The finest, or dwarf brooms, obtain as high as 25c. per lb. In well-selected dwarfs, a species of which is hereby sent by mail, please note the general fineness of the fibre, and you will also note that fully 4 inches of stalk are allowed to remain; this might with advantage be extended to 5 inches. The next grade is what is called "Self-working." These are composed as per sample attached, and have stems of fully 5 to 6 inches remaining, and

in the finer grades 7 inches are not a drawback. This class can be divided into two grades, the heavy, coarse piece being valued at about 3½c. per ℔., while the smaller piece is worth from 5c. to 7c. per ℔. But, taken as a whole, in what is contained in the "Self-working" bales, prices run about 5c. per ℔. In this class the entire lengths must be from 18 to 30 inches.'

Broom corn is usually shipped in bales. Any form of baling press, such as is used for hay or cotton, can be used. The bales usually weigh about 300 ℔. and are, on the average, about 4 feet long, 2½ feet wide, and 2 feet deep. In baling, the brush is laid with the heads overlapping in the centre with the stalks or butts outwards, the whole being tightly pressed. For the American market the bale is tied with ordinary fencing wire.

YIELD.

On this point Dodson says: 'A good crop of broom corn should yield 500 ℔. to 800 ℔. of brush per acre. The price varies from $40 to $200 per ton. Fluctuations are very great.'

Marks (*Agricultural Gazette* of New South Wales) places the yield higher, viz., 'from 8 cwt. to 12 cwt. of clean marketable brush, and 25 to 30 bushels of seed per acre. The prices vary from £18 to £40 per ton for the former, and, if not consumed on the farm, the latter is worth about 4*s*. per 4-bushel bag.'

The production of broom corn in New South Wales in 1904, from 2,212 acres, was 16,449, or on the average a little over 8 cwt. per acre.

FERMENTATION CHANGES OCCURRING IN MUSCOVADO SUGARS.

BY THE HON. FRANCIS WATTS, C.M.G., D.Sc., F.I.C., F.C.S.,

and H. A. TEMPANY, B.Sc., F.I.C., F.C.S.

Attention has already been called by one of us to the occurrence of fermentation changes in muscovado sugars in the West Indies, whereby the polariscopic test is subjected to alteration. (See *Agricultural News*, Vol. IV, p. 99.) No mention was, however, made of the scientific aspect of the phenomena. It is proposed here to give a brief account of the various facts arrived at, and any inferences that may be drawn therefrom. The most salient features in the phenomenon of fermentation in muscovado sugar are: (1) The variation in polariscopic test; (2) the escape of gas; and (3) the presence of a most distinct and characteristic vinous odour, which, if the sample is enclosed in an air-tight vessel, after a time becomes very strong indeed. Further, if a fermenting sugar is kept for any long period of time, it undergoes a very marked deterioration in appearance; thus a fermenting muscovado sugar, which in the first instance was fairly clear and bright, after six months' confinement in a stoppered glass jar had become a very wet, black sample of thoroughly objectionable appearance.

That raw sugars are liable to deterioration on storage is well known. The phenomenon has been described and dealt with by various authorities, namely, Shorey in Hawaii, Brown in Louisiana, and Greig Smith and Steel in New South Wales, who have all described a similar phenomenon, namely, the gradual fall in polariscopic test of raw sugars on keeping.

The occurrence of the phenomenon in these islands seems to run concurrently with the appearance of 'gum' in the juices and 'massecuites' in the boiling house. Whether this connexion is intimate or only chance is not clear; it may be purely fortuitous by reason of the fact that gum-containing sugar, draining badly, as it does, affords a better medium for bacterial growth than dry, well-drained sugar. It is noteworthy in this connexion that gum in juices and fermentation in sugars appear far more likely to occur in seasons of drought. As regards the frequency of its occurrence, the following is of interest: In April 1904, out of thirty-six sugars examined sixteen, or 41·7 per cent., were found to be fermenting strongly. In May and June 1905, out of thirty-nine sugars examined twenty-four, or 61·5 per cent., were found to be fermenting. It may be mentioned that both 1904 and 1905 were years of drought in Antigua, 1905 being especially dry.

In order to obtain an insight into the changes taking place, several series of analyses were made upon samples of fermenting sugar.

The first experiments undertaken consisted in making a series of observations, at stated intervals, of the polariscopic

test of a number of fermenting muscovado sugars. The results obtained by this method have already been given in the *Agricultural News*, but are included here for completeness. They are as follows :—

POLARIZATIONS AT VARIOUS DATES.

	April 16.	April 23.	April 30.	May 7.	May 14.	May 21.	May 28.
1	86·1	87·1	86·9	86·8	86·4	86·5	86·7
2	88·0	88·5	88·2	88·4	88·2	88·3	88·5
3	86·9	87·9	87·7	87·4	87·0	87·2	87·0

	June 4.	June 11.	June 25.	July 2.	July 9.	August 13.	October 3.	1905. March 31.
1	86·7	86·4	86·1	86·3	86·8	84·9	83·5	...
2	88·4	88·2	88·0	87·6	87·4	...	...	...
3	87·2	86·9	86·7	86·4	86·3	85·4	83·0	82·5

It is obvious that, however important the variation in polariscopic test may be from a commercial point of view, yet from a scientific stand-point it by itself affords little information beyond the fact that important alterations in composition are actually going on, since the polariscopic test is not the measure of the actual sucrose present but simply the algebraic sum of the opticity of all optically active compounds present in the sample. Hence, to obtain information from which reliable deductions may be drawn, it is necessary to make a series of analyses of fermenting sugars in order to ascertain how, not merely the polariscopic test, but also the actual constituents are varying as a result of the progress of fermentation.

For this purpose a sample of massecuite from a gummy juice was procured from a muscovado estate, and cured in a laboratory centrifugal. In the process of curing it was found that 4 kilogrammes of massecuite gave 2,872 grammes of centrifugalled sugar or 71·8 per cent. This sugar was stored in a well-corked bottle, and samples were withdrawn for analyses at regular intervals. The results of these analyses are given

in table A. A sample of ordinary muscovado sugar, not centrifugalled, was also examined, the results being recorded in table B :—

TABLE A.

1904.	May 6.	May 13.	May 20.	May 27.	June 3.	June 10.	June 17.	June 21.
Polarization	88·8	88·9	91·0	91·3	91·6	91·3	91·1	91·0
Total organic solids ...	98·1	97·6	97·6	96·1	95·5	96·7	97·2	97·9
Reducing sugars ...	3·58	3·41	2·49	2·22	2·20	1·94	1·05	0·65
Ash	1·05	1·05	1·05	1·05	1·05	1·05	1·05	1·05

TABLE B.

1905.	March 13.	March 17.	March 23.	April 3.	July.
Polarization	87·3	87·9	88·1	88·0	82·1
Total organic solids ...	91·8	90·60	93·50	93·80	90·6
Reducing sugars	2·91	1·75	1·17	0·80	0·38
Ash	1·42	1·42	1·42	1·42	1·52

The reducing sugar was determined by Fehling solution, the ash by sulphating and correcting according to Heron, the total solids from the specific gravity of a 10-per cent. solution, using a correction for the effect of ash on the specific gravity. The most striking features in the results obtained are: (1) the regular variation of the polariscopic test, in all cases, comprising a period of rise followed by a period of fall; (2) the diminution in the reducing sugars content.

At first sight it would seem as if the disappearance of the reducing sugar, supposing it to consist entirely of invert sugar, would account for the rise in polariscopic test. This is, however, not the case, as a closer examination will show; for whereas the disappearance of reducing sugar proceeds fairly steadily throughout the entire period covered by the experiment, the polariscopic test shows, concurrently with the disappearance

of reducing sugars, a period of rise in test followed by a period of fall, a fact obviously incompatible with the theory that the change is simply due to the disappearance of invert sugar.

Examining series A, we find that, between May 6 and May 27, the polariscopic test has risen from 88·8°V. to 91·3°V., a rise of 2·5°V. During this time 1·36 per cent. of reducing sugar has disappeared. As the sugar had only recently been manufactured, we may fairly assume that the reducing sugar originally present was almost entirely invert sugar.

The temperature at which the experiments were conducted was fairly close to 30°C. If we assume that the reducing sugar which has disappeared is invert, then at 30°C. the disappearance of 1·36 per cent. invert sugar would occasion a loss of laevo-rotation of 0·37°V., an amount quite insufficient to account for the rise in test experienced.

On the other hand, if we calculate what the optical effect would be if only the levulose of the invert sugar had been destroyed, we find that the disappearance of 1·38 per cent. levulose at 30°C. would occasion a decrease in laevo-rotation of 1·84°V., assuming $[\alpha]\frac{D}{30}$ for levulose to be 89·40° (angular).

The actual rise in test observed is, as stated above, 2·5°V., a quantity sufficiently close to that observed to warrant the suggestion being made that the rise in test during the first part of the fermentative process may be largely due to disappearance of the levulose of the invert sugar in the sample, the dextrose remaining comparatively untouched.

Series B does not exhibit the same amount of regularity, but it must be borne in mind that the sample was somewhat gummy and had a considerable preparation of admixed molasses, the impurities of which would tend to mask the effect of the fermentation.

This hypothesis is borne out by the following additional experiment: a sample of sugar was examined which originally showed as follows:—

Direct polarization	89·9°V.
Reducing sugar	2·97 per cent.

The sample was fairly clean and dry at the time the examination was made, and did not appear to be in a fermenting condition, but the phenomena of fermentation subsequently exhibited themselves. Three weeks from the time of the first examination it was again examined with the following result:—

Polarization	91·1°V.
Reducing sugar	2·34 per cent.

This shows that 0·63 per cent. of reducing sugar has disappeared, which, calculated as levulose, would account for a laevo-rotation of 0·85°V. at 30°C. The actual rise in test observed is 1·2°V. Bearing in mind that it is by no means certain that the products of the metabolism of the reducing sugar are optically inactive, we have here a distinct confirmation of the above hypothesis.

It must be borne in mind that this phenomenon is only clearly evidenced when the sugar is at, or approaching to, the top of the curve of rise in test; and, further, that it is best shown in clean sugars, which contain a relatively small proportion of molasses; the presence of a large proportion of molasses renders the effect liable to become masked by subsidiary changes.

Now, although the above hypothesis may account for the rise in test experienced, it by no means accounts for the subsequent fall that occurs. To do this we must proceed a step further.

It is suggested that the organism or organisms, to the growth of which the phenomenon is due, though preferably feeding on levulose, may, in the absence of levulose. feed on dextrose. This is supported by the fact that, in fermenting sugars, reducing sugars are continuosly disappearing, both before and after the maximum rise in test is experienced. In fact, a point is reached in the fermentation when the reducing sugars in the sample attain a minimum.

To investigate this point the following experiment was performed :—

A sterile solution of dextrose* was prepared by converting starch with sulphuric acid and afterwards neutralizing and removing the acid by means of lime. The solution was filtered, traces of plant food were added, the solution was divided into two equal portions, and each portion sterilized intermittently. One portion was inoculated from a fermenting sugar, the other was left sterile. In the inoculated solution growth occurred. After three months' standing both sterile and inoculated solutions were polarized :—

Inoculated solution polarized	=	5·0°V.
Sterile solution ,,	=	55·0°V.

This demonstrates clearly the power of the organism to feed on dextrose, and affords an explanation of the first part of the subsequent fall in test after the maximum has been attained.

We have therefore arrived at a fairly satisfactory explanation of a part of the facts observed, namely : (1) the original rise in test, (2) the considerable excess of the polarization over the actual sucrose on inversion, (3) the first part of the subsequent decrease in polarization. It seems, therefore, that the apparent increase in the sucrose content, as judged by the polarization, is not real, being due merely to the disappearance of optically active levulose.

Some small concentration of sucrose must take place owing to the escape of some of the decomposition products as gas, but otherwise, in the first stages, the sucrose content appears to vary but little.

A word as to the evolution of gas may not be out of place at this stage. It is one of the most striking features of the

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* d. Glucose.

whole course of fermentation, and begins quite early in the usual course. Various samples of sugar examined were found to be giving off gas abundantly.

The centrifugalled sample A was examined in this respect; 100 grammes of the sugar were placed in a flask with a gas-delivery tube, and the gas evolved collected and measured. The sample commenced to give off gas three days after the experiment was set up and continued doing so for thirty-eight days; in that time 135 c.c. of gas were evolved. The gas appeared to consist almost entirely of carbon dioxide.

The effect of the evolution of gas is strikingly shown if a cylinder is filled with fermenting sugar and the sugar lightly rammed down. In about thirty-six hours the escape of gas will cause the sugar to swell up and protrude above the mouth of the cylinder.

In the later stages of the fermentation, sucrose begins to disappear. This is not very obvious from the figures already given, but one or two more analyses may serve to elucidate this point.

Thus a sample of sugar, which by Clerget's method of inversion showed 85·44 per cent. sucrose, six and a half months later showed only 81·71 per cent. Similarly the sugar in series B on April 3 showed 87·69 per cent. sucrose by Clerget; in July it showed 82·08. Again, a sugar on July 21 showing 84·3 per cent. showed on September 18, 83·8 per cent. These facts indicate that, after long keeping, fermenting sugars do suffer actual loss of sucrose.

This is already well known, and has been dealt with by various authorities, viz., Greig Smith and Steel in New South Wales, Brown in Louisiana, and Shorey in Hawaii, who have in all cases described a similar phenomenon, namely, the steady drop in test of raw cane sugars on keeping; but none of them appear to have noted any previous rise. This is probably due to the fact that all were working on grey crystal sugars, which, containing little or no reducing sugar, would naturally not show it. The point at issue now is: To what is this drop in test due? Greig Smith and Steel find that it is due to a bacillus which they have named *Bacillus levaniformans* and which, according to them, first inverts the sugar and then subsequently converts the product into a gum, called by them levan.

In the case of muscovado sugar, it was found that, when sterile solutions of pure sucrose containing traces of plant food were inoculated from fermenting sugars, growth always occurred, first as a ropy appearance on the surface of the liquid and on the sides of the containing vessel, and, after some weeks' growth, as a thick white deposit.

Analysis of such an inoculated sugar solution showed as follows:—

A. Sterile solution.

Polarization $= 18{\cdot}8^\circ V.$

Reducing sugars = nil.

B. Inoculated sugar after one week's growth.

Polarization = 1·7°V.

Reducing sugars as glucose. } = 8·90 per cent.

These results show clearly the inverting action of the bacterium in question.

Thus we arrive at the following explanation of the activities of the organism or organisms concerned :—

(i) Reducing sugar consuming with a preference for levulose. (ii) Invertase secreting for the purpose of producing material for subsequent metabolism by the organism. That gum is produced as a product by the action of the organism was proved by treating a sugar solution, in which the organism had been growing for some time, with strong alcohol, when a distinct precipitation of gum was obtained, in appearance resembling that described by Greig Smith and Steel.

No satisfactory information was obtained as to the chemical or physical properties of this gum, the attempts to purify it not proving satisfactory.

At the same time some light was thrown on the character of the products of fermentation by determining on fermenting sugars the direct polarization and the true sucrose by Clerget's method of inversion. These results tend to show that, at any rate at a certain stage of the fermentation, dextro-rotating substances are formed. They are given in tabular form below :—

Direct polarization.	True sucrose (Clerget).
91·1	90·2
87·1	84·8
86·7	85·3

The true sucrose was determined and calculated by a modification of Herzfeld's method of performing Clerget inversions.

In the above results the excess of the direct polarization over the true sucrose content is too great to be accounted for by the dextro-rotation of the dextrose equivalent of the levulose consumed, and it is tentatively suggested that one of the first products of the metabolism of reducing sugar by the organism or organisms concerned may be dextro-rotatory.

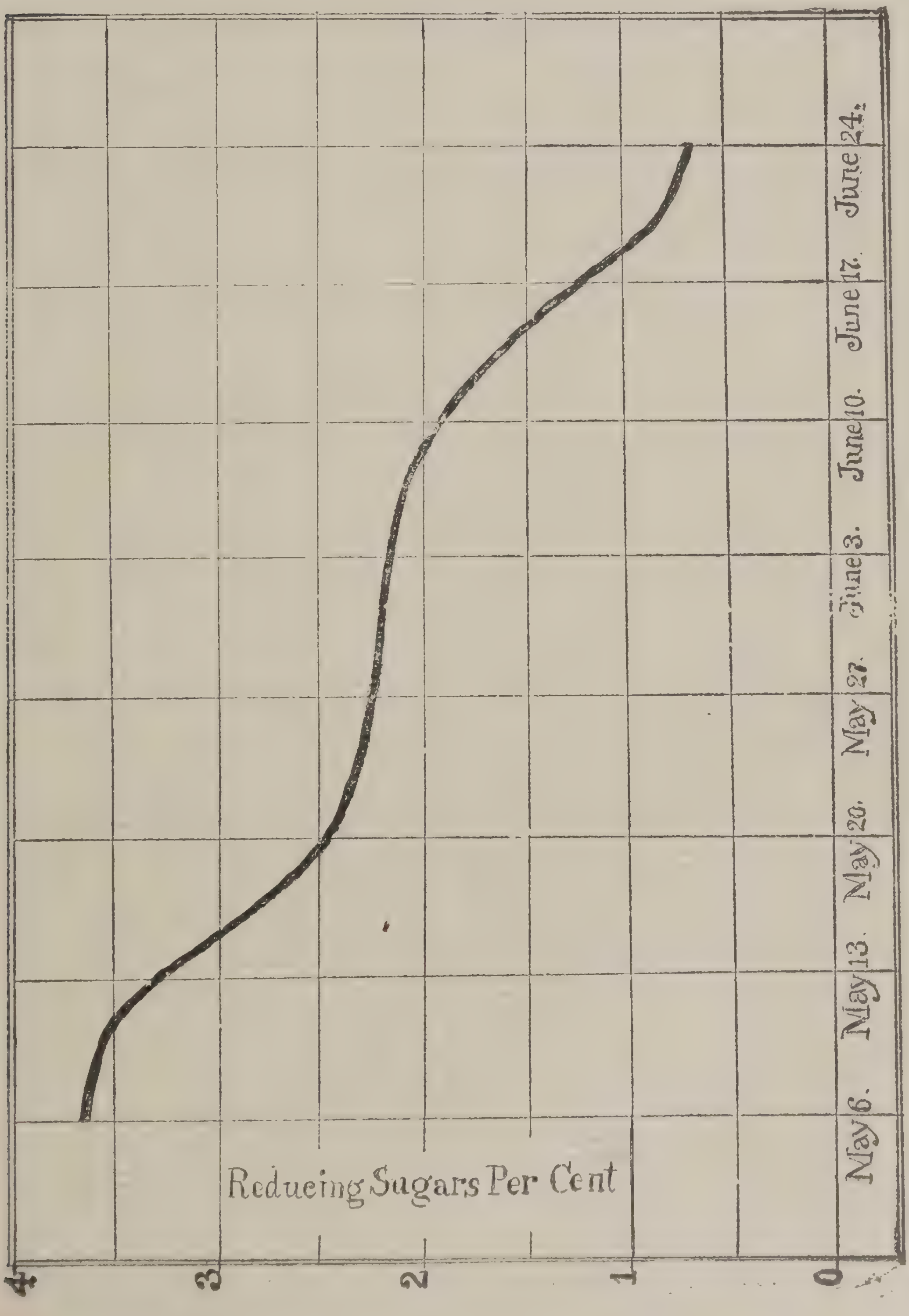
All fermenting sugars do not exhibit this excess of direct polarization over sucrose, as about half the samples examined showed a true sucrose content very closely approximating to, or slightly above, the direct polarization.

If the curve is plotted of the rate of disappearance of the reducing sugars in table A, as in the diagram, we see that the rate of disappearance is not uniform but varies regularly. A period of slow disappearance of reducing sugars regularly follows a period of rapid disappearance, pointing to the formation of some intermediate non-reducing body, as the result of the organism's activity, which is subsequently further

metabolized. It may be that this intermediate body is the dextro-rotatory substance, the existence of which is indicated by the above results.

This of course is largely speculative, but at the same time opens up a field for further work.

CURVE SHOWING RATE OF DISAPPEARANCE OF REDUCING SUGARS IN SERIES A.



The growth obtained on inoculating sucrose solutions with fermenting sugar shows the prevalence of gum-forming organisms. It may be that these organisms have some connexion with the formation of gum in canes and in juice.

Greig Smith and Steel suggest that the gumminess of certain juices is due to the presence therein of *Bacillus levaniformans.* The presence of a gum-forming organism in these islands renders this hypothesis tenable, but up to the present we have rather inclined to the view that here gummy juices are connected with special physiological conditions of the cane induced by drought and unsuitable conditions of growth.

Microscopic preparations from cultures in sterile cane sugar solutions revealed the presence of numerous oval free bacteria, 1–2 micro-millimetres in length and 0·5 micro-millimetres in diameter, agreeing fairly with Greig Smith and Steel's descriptions of the organism which they obtained. In addition, the preparations showed a number of torula-like forms.

Greig Smith and Steel state that the spores of their bacillus are capable of resisting exposure to a high temperature for a considerable length of time and suggest that on this account the bacillus, in spore form, is able to withstand the various operations occurring during the process of sugar making, and, entering the factory in the juice, can successively pass through defecators, eliminators, triple and vacuum pan and appear in the finished sugar in form ready to develop under favourable conditions.

This does not altogether fall in with experience obtained with muscovado sugar, as is shown by the following experiment:—

Strongly fermenting sugar was placed in a series of flasks, the necks of which were plugged with cotton wool; the flasks were then heated to 100°C. in the steam oven for one and a half hours. At the end of that time the flasks were withdrawn and put on one side. From time to time one of the flasks was opened, and the sugar in it withdrawn and polarized; a quantity of the same sample of sugar, which was not sterilized, was reserved for comparison. The following are the results obtained:—

No.	Date on which polarized.	Polarization of unsterilized sugar.	Polarization of sterilized sugar.
	1905.		
1	March 14.	86·9	87·0
2	„ 21.	87·5	87·1
3	„ 27.	...	87·1
4	April 10.	87·4	87·3
5	May 30.	85·7	88·5
6	Sep. 15.	81·6	88·7
	1906.		
7	Sep. 15.	79·7	88·8

On comparing these figures, we see that in six months, where an unsterilized sugar first rises to something over 87·5 and afterwards drops to 81·6, a sterilized sample in the same time has gained 1·7 in test and apparently shown no signs of any falling off. This rise is probably attributable to drying, as the sugar was rather a wet sample, and the various lots were merely confined in flasks, the necks of which were plugged with cotton wool, which would by no means check all evaporation.

We therefore see that heating to 100° C. for one and a half hours has sufficed to sterilize completely the sample of sugar experimented with, a fact not in accordance with the idea of the existence of a spore-bearing organism of an extremely resistant type. It is, of course, possible that the particular sample selected did not contain any spores, the bacteria being actively vegetative, nevertheless the experiment appears to have a distinct practical bearing for the sugar manufacturer.

As to means of treatment, it would appear that the method recommended by Greig Smith and Steel for dealing with their bacillus in New South Wales is equally suited to muscovado practice. It is as follows :—

'Obviously our aim should be so to check the growth of the organism as to prevent any formation of spores inside the walls of the factory. In dealing with the various syrups and liquors this can readily be done by taking care that these do not lie for any longer time than can be avoided, but are kept hot and worked up as rapidly as possible. In the refinery special attention should be given to the thin runnings and sweet waters, from filters, char-cisterns, etc., as these are particularly liable to bacterial growth of many kinds, whilst in the sugar mill the cane juice itself forms a perfect pabulum for the same class of organisms. Further, every care should be taken, by frequent washing, to keep all tanks and vessels scrupulously sweet and clean. But more than this will be necessary. Not only must the vessels themselves be kept clean, but the floors and surroundings also. Any pools or dark corners in which spilling and splashes of saccharine liquids can lie and ferment will quickly become points of infection, from which crops of spores, not only of the organism which we have been considering, but also others, perhaps equally harmful, may contaminate everything in the factory. By preventing the growth of the bacillus during the process of manufacture or of refining, we shall have gone a long way towards the finished sugar free from this objectionable organism.'

Although we are not inclined to accept the view that the spores of the organism producing the changes we have noted can survive the boiling incidental to the manufacture of muscovado sugar, still we endorse the view that cleanliness in the boiling house and in the curing house is the most likely means of reducing the attack.

In this connexion it is probable that the occasional washing down of the sugar house with disinfectant solution would be of use. For a similar purpose in breweries, H. Schnegg, in a paper recently published, and abstracted in the *Journal of the Society of Chemical Industry*, January 1906, recommends

a $\frac{1}{2}$-per cent. formaldyhyde solution, which he states gives excellent results as a germicide, and is without action in pipes, etc. The use of a similar solution in sugar houses would probably be beneficial in checking the growth of organisms.

GENERAL CONCLUSIONS.

Muscovado sugar is liable to fermentive changes whereby the polariscopic test increases and then falls. During the changes the amount of reducing sugar diminishes in a very marked manner.

These changes are due to micro-organisms and are checked by sterilizing by heating.

Part of the rise in polariscopic test appears to be due to the destruction of levulose.

The subsequent fall in test is due to destruction of dextrose and sucrose; at the same time the non-sugars appear to be increased.

The importance of the fact that raw sugars are liable to deterioration through bacterial agency on storage is great, and every effort should be made, through scrupulous care and cleanliness in the process of manufacture, to minimize the risk of infection of sugars by these dangerous organisms.

UTILIZATION OF ATMOSPHERIC NITROGEN FOR AGRICULTURAL PURPOSES.

In view of the ever-increasing consumption of nitrates for agricultural purposes, the prospect of a failure of the existing sources has always been viewed with considerable alarm. Consequently, the attention of chemists has long been turned to the problem of making the supply of atmospheric nitrogen available for plant food. It was not, however, until 1903 that the realization of this, on a commercial scale, seemed to be possible. Dr. A. Frank, of Charlottenburg, then announced that the fixation of atmospheric nitrogen could be effected through the agency of the carbides of barium and calcium. By the absorption of atmospheric nitrogen calcium carbide was shown to be convertible into calcium cyanamide, which could be directly used as a manure for supplying nitrogen to plants. This substance has since been prepared on a commercial scale in Germany and placed on the market under the name of 'Kalkstickstoff.'

The progress of science has placed at the disposal of the agriculturist another new nitrogenous fertilizer known as nitrate of lime. By means of electricity the nitrogen and oxygen of the atmosphere are combined to form nitric acid, which is converted into calcium nitrate, or nitrate of lime, by being passed into milk of lime.

In view of the great economic importance of these new sources of nitrogen, the information contained in the following pages has been collected from various scientific publications. Although, in some respects, the different articles cover the same ground, they will be found to give a complete account of the subject of the utilization of atmospheric nitrogen, dealing not only with the manufacture of these two new fertilizers but also with the results of various tests of their efficiency :-

The following review of Frank's paper, published in *Zeitschrift für Angewandte Chemie*, appeared in the *Experiment Station Record* (Vol. XV, December 1903, p. 347) :—

This is the full text of a paper read before the International Congress of Applied Chemistry at Berlin, in 1903.

In it the author gives statistics of consumption of nitrogen compounds to show the importance and desirability of some practical means of utilizing atmospheric nitrogen for industrial purposes. He reviews the history of attempts to fix the free nitrogen of the air in the form of nitrates, cyanides, and ammonia, from Priestley's experiments in 1785 in oxidizing the atmospheric nitrogen by means of the electric spark, to the recently proposed methods of preparing cyanamide by passing atmospheric nitrogen freed from a large part of the oxygen, normally associated with it in the air, over fused carbides of the alkali earths or by fusing a mixture of calcium carbonate and coal in presence of the nitrogen gas in an electric furnace.

In this connexion he refers to the work of himself and Caro, beginning in 1895, on the preparation of carbides of the

alkali earths, originally with a view solely to the manufacture of cyanides, experiments being made first with barium carbide and later with calcium carbide. It was found in these experiments that the fixation of the nitrogen by barium or calcium carbide did not result in the formation of barium or calcium cyanide, as was expected, but in barium or calcium cyanamide ($BaCN_2$ or $CaCN_2$), which yielded cyanides on fusion with alkali salts. By heating the cyanamide with water under high pressure, calcium carbonate and ammonia were formed as follows: $CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$. The better grade of cyanamide prepared by the above process contains from 14 to 22 per cent. of nitrogen. By dissolving the cyanamide in water and crystallizing in the cold, a dicyanamide, $(CN_2H_2)_2$, containing 66 per cent. of nitrogen, was obtained. This is a white salt resembling ammonium chloride.

The fertilizing value of the cyanamide (the so-called lime nitrogen) is discussed, and the experiments of Gerlach and Wagner are referred to as establishing the high value of the product for this purpose.

The *Experiment Station Record* (Vol. XV, September 1903, p. 25) has the following review of a paper by Gerlach and Wagner:—

In the preparation of acetylene gas from calcium carbide there is formed an impure calcium cyanamide mixed with carbon and caustic lime. This product contains from 15 to 25 per cent. of nitrogen which has been designated 'lime nitrogen' and is recommended for use as a fertilizer. Pot and field experiments with oats, barley, mustard, and carrots indicate that the nitrogen acts quickly and is almost as effective as nitrate. It was used in large amounts without injurious effects on the crops.

The *Experiment Station Record* (Vol. XV, January 1904, pp. 423-5) has the following editorial note on the subject of the industrial utilization of atmospheric nitrogen :—

Ever since the discovery by Priestley and Cavendish, in 1785, that the nitrogen and oxygen of the air can be made to combine under the influence of the electric spark, the question of preparing nitrogenous compounds from the free nitrogen of the air has engaged the attention of scientific men from time to time. It is only within comparatively recent years, however, that the great industrial importance of utilizing this vast store of nitrogen has been fully realized, and serious attempts made to develop practical processes of rendering it available for commercial purposes.

The matter is highly important from an agricultural standpoint, for, as every one knows, nitrogen is the most expensive of the fertilizing constituents and is restricted in supply. The exhaustion of the nitrate deposits, which constitute so prominent a source of supply, has been placed by reliable estimates at a matter of only a generation or so distant. The air contains nitrogen enough for all, and it has seemed highly probable that, ultimately, a way would be found for utilizing it for other plants than legumes.

Siemens and Lovejoy and Bradley have made important advances in this direction by the use of high-power electric currents for producing nitric acid from the nitrogen of the air. The development in 1894 by Moissan and Willson of an efficient electrical method for preparing calcium carbide has done much to ensure the success of a very different process of fixing the free nitrogen of the air, namely, in the form of cyanamides of the alkaline earths. The recent work of Frank and Caro, Pfleger, Erlwein, Rothe, and others in the development of this method gives reasonable ground for hope that the problem of the manufacture of nitrogenous compounds from the nitrogen of the air in a practical way has to a large extent been solved.

The investigations of these men show that by fusion of the carbides of the alkaline earths, especially calcium carbide, in the presence of atmospheric nitrogen, freed from the larger part of the associated oxygen, calcium cyanamide is produced. In practice it is found best to combine the preparation of the calcium carbide and of the cyanamide into a single operation, by starting with a mixture of calcium carbonate and coal (as in the making of carbide) and fusing these in the presence of the deoxygenized air. The crude product formed has admixed with it more or less lime and carbon, and contains from 10 to 22 per cent. of nitrogen. By further treatment this product can be made to yield free ammonia, cyanide, or dicyanamide containing 66 per cent. of nitrogen, and other compounds. The experiments of Gerlach and Wagner, however, indicate this to be unnecessary from an agricultural standpoint, since the cyanamide can be used directly as a fertilizer. It has no injurious effects on plants, and shows an efficiency fully equal to, if not exceeding, that of the ammonium salts, and but slightly inferior to that of nitrate of soda.

The preparation of the calcium cyanamide is comparatively simple and cheap. A company has been organized in Berlin for the manufacture of nitrogenous compounds by this process, and if further experience fulfils the promise of the earlier work, it seems quite probable that this new source of nitrogen for fertilizing purposes will soon find its way into the markets, and the experiment stations will be called upon definitely to determine its agricultural value.

The *Experiment Station Record* (Vol. XVII, April 1906, pp. 764-7) contains the following review of a paper by O. N. Witt, in the *Chemiker-Zeitung*, on the subject of the utilization of atmospheric nitrogen :—

This article reviews the various attempts which have been made from the time of Cavendish to prepare nitrogen compounds from the free nitrogen of the air, including the more recent attempts of Bradley and Lovejoy, of the Atmostpheric Products Company, of Niagara Falls, and Frank's calcium cyanamide (lime nitrogen) process.

It is claimed that the former has proved too costly to be a commercial success. The commercial success of the latter depends upon the possibility of securing cheaper methods of producing electrical energy and of freeing the nitrogen of the air from its associated constituents. The most promising

results with the Frank process, from a commercial standpoint, have apparently been obtained in Italy, where cheap and abundant water-power has been utilized in the generation of electrical energy.

The most successful electrical method which has yet been suggested, judging by the results reported, is that of K. Birkeland and S. Eyde, of Christiania, Norway. The inventors of this process, for which patents have been taken out in this country as well as in Europe, claim that it has not been possible up to the time of their discoveries to utilize electric energy in a single powerful arc for the production of nitric compounds from the atmosphere in an economical manner.

As stated in the United States patents, their invention is based upon the fact that electrical discharges between electrodes placed within a magnetic field may be dispersed by the action of the magnets, and that 'an electric arc of high or low tension may be dilated or spread into a large permanent flame having the shape of a sheet or a disk of a volume several hundred times as large as a regular or primary arc of the same energy, when the electrodes are placed in a suitable manner in a powerful magnetic field, for instance, between the poles of a magnet and transverse to the flux of said field.'

In this way it is possible 'to transform a great part of the electrical energy into heat capable of being absorbed by certain gases, as chemical energy under conditions which are attended by valuable chemical reactions. This is due to the fact that the efficiency of a flame in endothermic chemical processes is a function of the ratio between the volume and the temperature of the flame. [It is claimed that by this process it is possible] to have furnaces at continuous work with several hundred kilowatts at each flame, the heat being economically utilized, a result which was not heretofore possible unless the energy employed for each arc was only very small.'

It is reported that, in works which have been built at Notodden, Norway, to utilize water-power from large falls in that vicinity, 1,500 kilogrammes per day of water-free nitric acid are now being made. The final product is in the form of calcium nitrate, the fertilizing value of which is being studied by a number of investigators.

A further editorial note on this subject appeared in the same publication (Vol. XVII, pp. 827-9) as follows:—

The notable progress which has recently been made in the development of commercially successful methods of fixing the free nitrogen of the air, and thus making it available for agricultural and other industrial purposes, should go far toward reassuring those who are disposed to view with alarm the rapid exhaustion of the world's principal known supply of combined nitrogen, namely, the nitrate deposits.

The rapidly increasing demand (which has arisen from less than 200,000 tons of nitrate in 1870 to over 1,500,000 tons in 1905) and the steadily diminishing supply have stimulated unusual activity in efforts to apply the discoveries of science to

the solution of the great industrial problem of finding a practical means of maintaining a cheap and reliable supply of fixed nitrogen.

The encouraging results yielded by the Frank and Caro calcium cyanamide process have already been referred to (*Experiment Station Record*, XV, p. 423). Further developments in the application of this process have fully justified the promise of the earlier trials, and factories have been built in Italy, Germany, and elsewhere to test the process on an extensive commercial basis. The numerous experiments which have been made to test the fertilizing value of the so-called lime nitrogen ('Kalkstickstoff') prepared by this process indicate that, when used with proper precautions and under certain restrictions, the product has a fertilizing value in general but slightly inferior to that of nitrate of soda and somewhat superior to that of sulphate of ammonia. The results of hundreds of such experiments on a great variety of soils and crops are given in a recent 120-page report issued at Rome.

Improvements are constantly being made which increase the efficiency of the process and lessen the cost of the product, and which encourage the belief that, where cheap water-power is available, this process can be made to yield a product capable of competing successfully with nitrate of soda in the markets of the world.

The most recent and most notable development in the line of fixation of the nitrogen of the air for commercial purposes is, however, in the nature of a return to the earlier methods of direct oxidation by the means of electric discharges. Professor K. Birkeland, of the University of Christiania, Norway, and S. Eyde, a Norwegian civil engineer, have devised a process for greatly increasing the size and efficiency of the ordinary electric arc, so that oxidation of the nitrogen is more rapid and is accomplished with much less expenditure of electric energy, and hence at less cost than in preceding processes.

A recent writer in describing the process says: 'The inventors, instead of working with arcs of the lowest possible amperage, make the first technical application of a phenomenon previously known to physicists, the action of the magnetic field on the arc.' They use a powerful current of electricity in the form of great glowing electric disks, up to 6 feet in diameter, which are built up of arcs deflected by powerful magnets.

By means of powerful electromagnets placed vertically to the electrodes, which are hollow and cooled with a stream of water, 'the arc formed between the electrodes is blown away, as it were, by the influence of the magnetic field, and at once a new arc is formed, which is blown away. This process can be repeated 1,000 times a second, though in practice only a few hundred arcs per second are used. With alternating-current arcs and direct-current magnetic field, or vice versa, the arcs vibrate between the electrodes as circular disks.' There is thus secured the alternate heating (to 2,000° C.) and cooling, and the rapid and thorough contact of the air with the most active zone of the arc, which are essential to the highest oxidation efficiency.

The efficiency of this process has been demonstrated in an experimental factory near Notodden, Norway, which utilizes the unusually cheap water-power of that region for the production of the electric energy required. It is reported that the daily output of this factory for the year during which it has been in operation is about 3,300 ℔. of pure nitric acid, and the factory has been pronounced a technical and financial success by the eminent authority, Otto N. Witt, of Berlin. The success of the experimental factory has been such that several larger establishments are being built at other places in South Norway where cheap water-power can be had. It is claimed that these factories will utilize in the aggregate about 30,000 horse-power, and that the company exploiting the patent has options on Norwegian waterfalls capable of yielding 350,000 horse-power at very low cost.

It is reported that nitric acid can be produced by this process at less than one-tenth of its present cost. Owing, however, to the dilution of the products of oxidation, the difficulty and expense are less in production than in concentration of the nitric acid. The latter has not yet found a perfect technical solution, and so it has been found most economical to market the product in form of calcium nitrate.

For agricultural purposes, especially, the calcium nitrate is mixed with an excess of lime, yielding a dry, easily handled material known commercially as 'lime nitre' ('Kalksalpeter'), which contains on an average 8 to 9 per cent. of nitrogen and about 22 per cent. of lime. A number of experiments have been made with this material, which indicate that it has a fertilizing value slightly superior to nitrate of soda on soils benefited by lime as well as nitrogen.

CYANAMIDE.

Mr. A. D. Hall contributed to the *Journal of Agricultural Science* (Vol. I, January 1905, pp. 746-8) the following general account of the manufacture of cyanamide and its utilization as a manure :—

Calcium cyanamide represents the first attempt on a commercial scale to bring atmospheric nitrogen into a state of combination ; to manufacture, in fact, an artificial manure containing nitrogen derived from the air. The starting-point for the manufacture is the well-known substance calcium carbide, which is produced by heating in the electric furnace a mixture of chalk and coke or some other form of carbon. The calcium carbide, now so generally employed for generating acetylene for lighting purposes, is almost wholly made where cheap power to produce electricity can be obtained from a waterfall, and the manufacture of calcium cyanamide must naturally take place alongside, so as to secure a cheap supply of carbide. The remaining process is simple enough ; the calcium carbide is reduced to a coarse powder, placed in a vessel resembling a gas retort and brought to a temperature approaching white heat, when a current of nitrogen gas is led over it until combination ceases. The result is a compound

containing nearly 20 per cent. of nitrogen, crude calcium cyanamide, the formula of which, when pure, would be represented by $CaCN_2$. The nitrogen required in the manufacture is obtained from the air in the simplest way by passing air through a heated cylinder packed with copper turnings; the oxygen combines with the copper and the nitrogen passes forward into a gasholder until required. The copper is regenerated by passing a current of coal-gas through the heated cylinder. The resulting crude calcium cyanamide is a fine black powder, which decomposes rapidly when heated with water under pressure, and slowly with water at ordinary temperatures, into calcium carbonate and ammonia, in accordance with the equation:—

$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3.$$

Cold water and the action of acids extract a substance dicyandiamide, $(CN_2H_2)_2$, noteworthy as containing two-thirds of its weight of nitrogen. This substance is of no service to plants, but appears to have some use in connexion with the manufacture of high explosives. From the crude calcium cyanamide it is easy to prepare the cyanides of sodium or potassium, and sodium cyanide, manufactured in this fashion, is now on the market.

The nitrogen in the crude calcium cyanamide is best determined by digesting it with strong sulphuric acid by the usual Kjeldahl's method.

The manufacture of crude calcium cyanamide has not yet been taken up on a large scale; a model plant is in operation in Berlin capable of turning out quantities of about 1 ton per diem, and arrangements are being made with other firms to develop the process commercially.

Through the kindness of the Cyanid Gesellschaft, of Berlin, the Rothamsted Experimental Station was furnished, in the spring of 1904, with 50 kilogrammes of the material, containing 19·7 per cent. of nitrogen. It was then too late to use it for any cereal crop, since it cannot be employed as a top dressing, but arrangements were made for experiments with roots.

As a manure it should be applied to the soil some little time before the seed is sown and should be lightly ploughed in, lest any loss of ammonia take place. It cannot well be mixed with other manures; with superphosphate, for example, the reaction is somewhat intense, and the whole mass becomes very hot. It was decided to compare its action with that of an equivalent amount of nitrogen in the shape of sulphate of ammonia, superphosphate and sulphate of potash being equally supplied to both. The Rothamsted soil is a somewhat heavy stony loam, almost a clay in the subsoil: the surface soil contains a fair supply (from 1 to 3 per cent.) of carbonate of lime, so that sulphate of ammonia is always an effective source of nitrogen. . . .

Speaking generally, the trials do not warrant any definite conclusion as to which is the better source of nitrogen, calcium cyanamide or sulphate of ammonia; two of the three experi-

ments would make the cyanamide as good a source of nitrogen as sulphate of ammonia, but, as has already been stated, one of these experiments may be considerably in error. The third trial, a very uniform and even experiment, which looked trustworthy, was decidedly in favour of the sulphate of ammonia; but, on the other hand, on this plot the cyanamide by mistake had been mixed with the other manures and burnt earth before sowing. Again, the stoppage of growth through the drought did not give the cyanamide as good a chance, if we may assume it requires time and plenty of moisture to set free all the ammonia.

There can be little doubt, however, that calcium cyanamide is an effective nitrogenous manure, though more extended experiments are necessary to decide whether the unit of nitrogen is worth more or less in its case than in sulphate of ammonia.

MANUFACTURE OF CYANAMIDE.

In the *Annual Reports* of the Chemical Society (Vol. I, pp. 194-5) on the progress of chemistry during the year 1904, the manufacture of cyanamide is discussed as follows:—

To deal now in more detail with the principal points comprised in the year's work, we take first the production of cyanamide and its application to agricultural purposes as a means of utilizing the nitrogen of the atmosphere and converting it into plant food. Frank, of Charlottenburg, gives in the paper which was read at the International Congress in Berlin, an account of his work on this subject, describing how, in conjunction with Caro, he had observed the taking up of nitrogen by the carbides of the alkalis and alkaline earths formed in the electric furnace. They experimented with the carbides of barium and calcium in particular, the latter being found the more applicable, inasmuch as the taking up of nitrogen by calcium carbide produced, not calcium cyanide, but a separation of carbon and formation of calcium cyanamide ($CaC_2 + 2N = CaCN_2 + C$). From this compound, by the interaction of water, ammonia would be formed ($CaCN_2 + 3H_2O = CaCO_3 + 2NH_3$). This substance could also be produced by heating lime to chalk with charcoal at 2,000° in a current of air. The product calcium cyanamide is sold in Germany commercially under the name 'Kalkstickstoff,' and contains from 14 to 22 per cent. of nitrogen, according to its varied method of preparation. It remained to put it to the test for agricultural purposes, and this was done by Wagner at Darmstadt and Gerlach at Posen, both by pot-culture trials and in the field, and with results that betokened success, it being stated that the effect of the cyanamide fell very little short of that produced by salts of ammonia containing the like quantity of nitrogen. The nitrogen of the calcium cyanamide is changed into ammonia in the soil, and this then undergoes nitrification. Although these favourable accounts of its use have been set out, it is evident that the material must be put more thoroughly to the test before a definite pronouncement can be made. In 1904, a field trial with it was undertaken at Rothamsted, in comparison with ammonium sulphate, but without any very

definite result. In Germany, the field trials were never as successful as those with pot culture, and there was evidence that with some soils, especially those of peaty nature, there was an injurious action. This is attributed to the formation of dicyanodiamide by the action of acids. Takke (*Bied. Centr.*, 1904, 33, 583; from *Mitt. Ver. Förd. Moorkultur*, 1903, 23, 347) states that a poisonous action was observed when the material was added just before sowing the seed, but not when an interval of two and a half months was allowed to elapse. It is evident, however, that, even if proved useful agriculturally, the success of cyanamide as a commercial enterprise must depend entirely upon the cheap production of electric energy, as where water-power is available.

USE OF CYANAMIDE AS A MANURE.

The results of experiments carried out to test the efficacy of cyanamide as a manure are reviewed as follows in the *Annual Reports* of the Chemical Society (Vol. II, 1905, pp. 243-4):-

In last year's report, an account was given of the manufacture of calcium cyanamide and its sale under the name 'Kalkstickstoff.' Further trials with it were made in 1905. At Rothamsted, A. D. Hall (*Jour. Agric. Science*, Vol. I, January 1905, p. 147) tried it in comparison with ammonium sulphate for mangels, swedes, and mustard, but the results were of indefinite character, and the most that could be said was there was nothing to indicate that cyanamide was, unit for unit of nitrogen, worth more than ammonium sulphate.

Cyanamide cannot be used as a top dressing, as loss of ammonia then takes place, nor can it be mixed with superphosphate or similar manures, since the mixture gets very hot. W. Zielstorff (*Bied. Centr.*, 1905, 34, 217), in conducting pot experiments with mustard, found that, when the cyanamide was sown with the seed, its value as compared with sodium nitrate was 88·4 : 100, whereas if applied ten days previous to the sowing of the seed the value increased to 92·8 per cent. Zielstorff also ascertained that cyanamide left practically no residue for a second crop to benefit by.

E. Haselhoof (*Jahrb. Landw. Versuchs-Stat.*, Marburg, 1904-5) showed that germination was injuriously affected if calcium cyanamide was present in the proportion of 0·025 gramme to 100 grammes of soil, but that harm might be avoided by application of the cyanamide well in advance of sowing of the seed.

C. von Seelhorst and A. Müther (*J. Landw.*, 1905, 53, 329), in comparing calcium cyanamide with ammonium sulphate found that in the case of a sandy loam the manurial value was about equal in the two cases, but that when used in sand-cultures, calcium cyanamide was injurious to vegetation, probably because of the presence of calcium carbide.

F. Löhnis (*Centr. Bakt.* Par., 1905, [ii], 14, 309) experimented with several different micro-organisms in order to see what effect they would have on calcium cyanamide. He found that *Bacterium Kirchneri*, *B. lipsiense*, *B. megatherium*, *B. vulgare*,

var. *Zopfi*, and others liberated ammonia from cyanamide at the ordinary temperature, and that aeration took no essential part in the process.

R. Perotti (*Chem. Centr.*, 1905, 2, 1,507), having previously shewn that for calcium cyanamide to act as a fertilizer it must undergo decomposition in the soil, experimented with it in conjunction with peat, and he then found that hydrolytic decomposition took place more rapidly than in aqueous solution, and that there was no appreciable loss of nitrogen. From this he was led to suggest the use of peat along with calcium cyanamide for the more rapid decomposition of the latter and to advise the use of peat with fertilizers containing calcium cyanamide.

In general, as regards the use of calcium cyanamide, it may be said that the evidence so far points to it being beneficial, although hardly to the same extent as ammonium sulphate, whilst its practical success in the future must depend entirely on the cost price at which it can be produced, as compared with ammonium sulphate supplying an equal amount of ammonia.

The most recent information in regard to the use of calcium cyanamide as a manure is contained in the following note by Mr. A. D. Hall, which is extracted from the *Journal of the Board of Agriculture* (Vol. XIII, July 1906, pp. 216-8):—

Calcium cyanamide, or 'Kalkstickstoff,' the new manure obtained by combining calcium carbide with the nitrogen of the atmosphere, seems likely soon to come upon the market on a commercial scale. Through the kindness of the Cyanid Gesellschraft, of Berlin, a trial quantity was received by the Rothamsted Experimental Station in 1905, and was used for barley and mangels, with the result set out below. The material was a fine black powder, which yielded on analysis 20·3 per cent. of nitrogen; it is thus, weight for weight, only a trifle poorer in nitrogen than sulphate of ammonia, which contains about 20·5 per cent. In all cases it was compared with sulphate of ammonia; phosphates and potash being applied equally on both the trial plots so as to provide a complete manure and match the nitrogen in the cyanamide against an equal amount of nitrogen in the sulphate of ammonia.

Taking the results together, and also considering those obtained in 1904, it is clear that the nitrogen in calcium cyanamide is practically of the same value as that in sulphate of ammonia. There is a slight balance of evidence in favour of the sulphate of ammonia, which is chiefly manifested in the early stages of the growth of the crop, probably because the cyanamide is a little slower in coming into action, but the differences in the results are small and within the range of errors of experiment. Again, the Rothamsted soil is fairly well supplied with carbonate of lime, hence the sulphate of ammonia can exert its proper action, while no benefit is derived from the carbonate of lime which is produced in the soil from the cyanamide. Calcium cyanamide is decomposed within the soil into ammonia and calcium carbonate. 1 cwt. of cyanamide giving rise to at least 140 lb. of carbonate of lime. On many

soils, particularly the clays and peaty soils, for which sulphate of ammonia is an unsuitable manure because it behaves like an acid, this carbonate of lime would be of value and should be counted to the credit of cyanamide as a manure.

The chief practical drawback to the use of cyanamide lies in the fact that it cannot be mixed with manures like superphosphate, but must be sown separately and scuffled into the soil some days before the seed is sown. The cost of production of cyanamide can only be settled when it has been put on the market on a commercial scale; it may, however, be taken as certain that if the manure can be sold on a parity with, or a little cheaper than, sulphate of ammonia, it may be employed by farmers on a large scale with every confidence of a good result.

CALCIUM NITRATE.

The other new nitrogenous manure—calcium nitrate—is also produced by the utilization of atmospheric nitrogen. The combination of nitrogen and oxygen is brought about by electricity. The manufacture of calcium nitrate and the results of its employment as a manure are discussed as follows in the *Annual Reports* of the Chemical Society (Vol. II, pp. 244-6):—

Undoubtedly the subject which has given rise, during the year 1905, to the greatest interest so far as agricultural science is concerned, is that of the discovery of a new method of utilizing atmospheric nitrogen. This has been effected by Birkeland and Eyde's process, which has been fully described by O. N. Witt (*Chem. Ind.*, 1905, 28, 699). Briefly, this consists in the production of nitric acid through the combination of the elements of the air under the influence of electricity generated in a furnace of great intensity. The nitric acid is then transformed into calcium nitrate by passing it into lime water, and subsequent manipulations result in the production of a salt which can be used directly on the soil as a fertilizer. That small quantities of nitric acid are formed under the influence of atmospheric electricity has long been known, but these amounts are far too small to be of any agricultural importance. In face of the conclusions arrived at by Lawes, Gilbert, and Pugh, that plants are unable to avail themselves of the uncombined nitrogen of the air and that it is in the form of nitrates that they take up nitrogen, recourse has been had to the use of sodium nitrate and other nitrate-yielding materials and to the cheaper production of these. If the atmosphere could be made to produce these nitrates in sufficiency, it is clear that an unlimited source of supply would be ready at hand. The present discovery, which may be described as Cavendish's experiment on a larger scale and carried out under more favourable conditions as regards electrical energy, has been achieved by Birkeland and Eyde at Notodden, Norway, where water-power of enormous extent is available. Atmospheric air is led into a specially constructed electric furnace, in which it is heated to a very high temperature under the influence of an electric arc spread out into disk-like shape by the action of powerful electro-magnets; oxides of nitrogen are formed from

the air thus introduced, and these are conveyed into a series of towers in which they are condensed in water and the liquors allowed to concentrate, the weak acid being used over and over again in the towers until a strength of about 50 per cent. is attained. The gases are then led into milk of lime, and after that over dry lime, whereby calcium nitrate is mainly formed. By treatment with nitric acid, a calcium nitrate. containing about 13·2 per cent. of nitrogen, is obtained as a salt, which can then be employed direct as a fertilizer of the land. One objection to the product, namely, its hygroscopic nature, has been overcome by R. Messel, who, by mixing the calcium nitrate so obtained with calcium oxide, or with calcium sulphate, and calcining the mixture, has obtained a basic calcium nitrate ($2CaO, N_2O_5$), which is non-hygroscopic and which, when powdered, can be readily applied to the land. It would, of course, be possible to obtain sodium nitrate in place of calcium nitrate by using sodium carbonate instead of lime, but the calcium nitrate is preferred both on account of the cheapness of the lime and because of the agricultural benefit which the use of lime will in many cases confer, more particularly when soils are deficient in this necessary constituent.

Practical trials have been made already with the calcium nitrate, and these would seem to indicate that it is just as effective as sodium nitrate, supplying the same amount of nitrogen. Indeed, there is no reason why this should not be the case. T. Schlœsing (*Compt. Rend.*, 1905, 141, 745, 746) carried out pot-culture experiments with maize, in which the use of calcium nitrate and calcium nitrite was compared with that of sodium nitrate and nitrite, respectively, and the calcium salts were shown to be equally as efficacious as the sodium ones. Also E. S. Bellenoux (ibid., 140, 1,190) experimented with calcium nitrate and sodium nitrate in the field on crops of potato and sugar beet, and found that the calcium salt gave in each case the better result. The calcium nitrate in these experiments, however, had not been obtained by the electric process above described, but from sodium nitrate and calcium chloride. whereas, in T. Schlœsing's experiments, the electrically-produced salts were used.

If calcium nitrate can be obtained by the electric process at a price at which, as regards its percentage of nitrogen, it can compare favourably with sodium nitrate, it is clear that enormous benefits are at hand so far as agriculture is concerned. So far, we have but little information to guide us as to what the cost of manufacture is, and it is still early, therefore, to build great hopes on the prospects. The provision of water-supply adequate for the production of electric power at a cheap rate is evidently the determining factor: but, from a scientific point of view, the discovery of this new process constitutes one of the most important advances of the century. It is to be hoped, however, that in the case of an undertaking possessing such far-reaching possibilities nothing will be allowed to interfere with its development on strictly scientific lines, and with its furtherance for the benefit of agriculture.

THE MANUFACTURE OF NITRATE OF LIME.

The following article, reproduced from the *Journal of the Board of Agriculture* (Vol. XII, January 1906, pp. 598-600) deals with the manufacture of nitrate of lime:—

The Board have received through the Foreign Office a dispatch from the British Consul-General at Christiania (Mr. Edward F. Gray), stating that a Norwegian company has been formed there, under the name of 'Norsk hydro-elektrisk Kraelstofaktieselskab,' to develop the Norwegian patents of Professor Birkeland, of the University of Christiania, and Mr. S. Eyde, a Norwegian civil engineer, for the production of nitrogen through the oxidization of air by means of their hydro-electric process, and for the manufacture of nitrate of lime for agricultural and other purposes.

According to the terms of the company's prospectus, the capital amounts to £388,920, of which £222,240 is in 8-per cent. preference shares, and the rest in ordinary shares. The Banque de Paris et des Pays Bas is understood to be largely interested in the undertaking, as well as Swedish capital.

The company has secured water-power of about 29,000 horse-power at the Svaelgfos waterfall, near Notodden, where the present saltpetre factory is situated, as well as the right to purchase other falls, including the well-known Rjukanfos of about 220,000 horse-power. The inventors claim for their process greater efficiency and economy than can be obtained by the more complicated system of Lovejoy and Bradley at Niagara, and also superiority over other known processes for the fixation of nitrogen from the air, such as that of the Deutscher Cyanid Aktiengesellschaft and others. Should the company prove successful, it seems that an industry of considerable importance will thereby be created in Norway.

The following is a brief description of the Birkeland-Eyde method, which is now in use in Norway for the manufacture of nitrate of lime from air by a hydro-electric process.

One of the main features in the process is a new kind of electric furnace, in which is produced a special flame which Professor Birkeland claims to have discovered while engaged in the solution of another problem. Together with Mr. Eyde, he has applied the flame to obtain a chemical combination of oxygen and nitrogen. In Professor Birkeland's experiment, the electrodes were placed equatorially between the poles of a powerful electro-magnet, with a fixed distance between the points of the electrodes of from 1 to 2 mm. A steady flame was created, causing a loud noise, and running through four octaves according to the strength of the electro-magnet.

Amongst the chemical reactions which can be caused by the flames is the oxidization of the nitrogen of the air.

Without going into the details of the construction of the furnaces, it may be stated that it is claimed that the flame is comparatively steady, and up to 1,000 horse-power can safely be carried on two 1·5-cm. water-cooled tubes of copper, which form the electrodes, thus producing a flame 1·8 metres in diameter; and, further, that these flames can burn con-

tinually without causing damage in a flat-shaped furnace about 8 centimetres wide and 2 metres long. Experiments in manufacture have passed through various stages, ending with an experimental station near Arendal, with 500 to 1,000 horse-power and absorption towers of granite, each measuring 40 cubic metres.

On May 2, 1905, the first nitrate factory was opened at Notodden. The factory contains three furnaces, each of 700 horse-power. These furnaces are stated to show great stability and regularity, and treat some 75,000 litres of air per minute, through which the flame is passed, producing a dark-brown substance named peroxyde of nitrogen. The gases are absorbed and transformed into nitric acid in two rows of stone towers, four in each row, each tower measuring 40 cubic metres. In each row, is a fifth tower in which the remaining gases are absorbed into lime water. It is claimed that about 95 per cent. of the nitrous gases can be absorded. The nitrate of lime produced is said to resemble salt, and to be easily dissolved in water, and a method has been found of transforming it into a basic salt which keeps dry, and which can be distributed in a granular form by means of agricultural sowing machines.

Experiments in the manurial properties of the Norwegian nitrate of lime compared with other products have been made at the Norwegian State Agricultural College, and it is claimed that it is equal to natural saltpetre in its results, and, indeed, superior on sandy soil on account of its chalky properties. It is also thought it may be employed in connexion with the manufacture of explosives and various colours.

Germany is said to take the product as fast as it can be supplied, but no doubt samples could be had on making application to the company ('Norsk hydro-elektrisk Kraelstofaktieselskab') who have taken over the manufacture. It would be useful if agricultural colleges and experimental stations in this country would obtain supplies of this material for experimental purposes.

ANTIGUA METEOROLOGICAL RETURNS, 1905.

The Hon. Francis Watts, C.M.G., D.Sc., F.I.C., F.C.S., has forwarded the following meteorological returns for Antigua. A paper on the 'Climatology of Antigua' appeared in a previous issue of the *West Indian Bulletin* (Vol. III, pp. 362-72), to which reference might usefully be made. The detailed rainfall may be useful in connexion with any inquiry as to the conditions under which cotton has been grown in various places in Antigua :

Average Monthly Rainfall, 1905.

(Mean of sixty-eight Stations.)

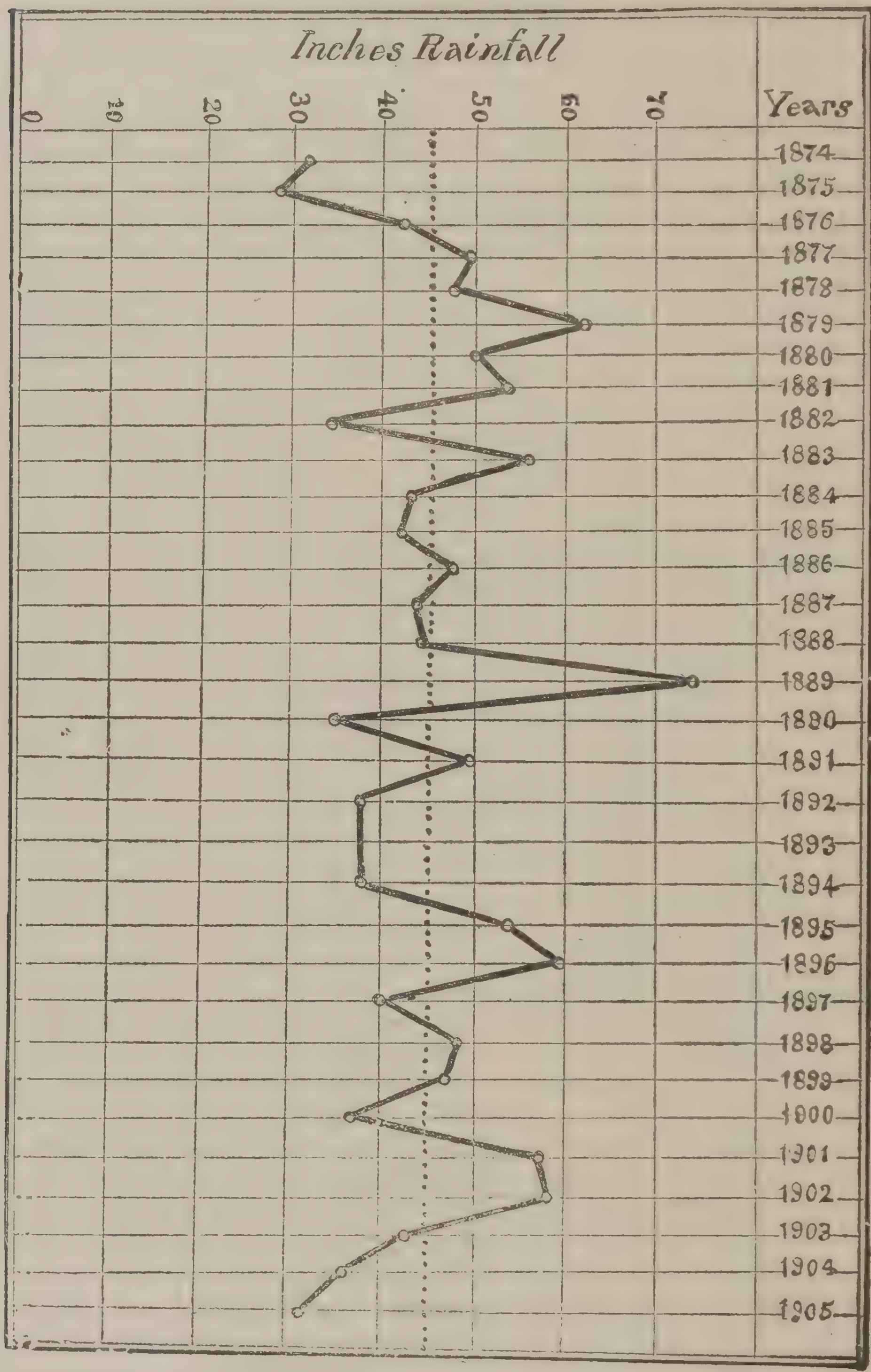
January	1·51
February	1·23
March	2·06
April	1·56
May	1·23
June	1·68
July	3·13
August	4·92
September	4·04
October	3·33
November	4·88
December	1·83
Total	31·40

Average Rainfall, 1874-1905.

In 1874	the average	rainfall	on	41	Stations	was	31·16
1875	,,	,,	,,	40	,,	,,	28·78
1876	,,	,,	,,	36	,,	,,	41·98
1877	,,	,,	,,	38	,,	,,	49·05
1878	,,	,,	,,	53	,,	,,	47·11
1879	,,	,,	,,	52	,,	,,	61·54
1880	,,	,,	,,	46	,,	,,	49·68
1881	,,	,,	,,	44	,,	,,	53·75
1882	,,	,,	,,	45	,,	,,	33·04
1883	,,	,,	,,	56	,,	,,	55·51
1884	,,	,,	,,	56	,,	,,	43 98
1885	,,	,,	,,	53	,,	,,	43·39
1886	,,	,,	,,	55	,,	,,	47·78
1887	,,	,,	,,	50	,,	,,	43·68
1888	,,	,,	,,	47	,,	,,	44·23
1889	,,	,,	,,	50	,,	,,	73·59
1890	,,	,,	,,	45	,,	,,	33·00
1891	,,	,,	,,	45	,,	,,	50·01
1892	,,	,,	,,	53	,,	,,	38·53
1893	,,	,,	,,	54	,,	,,	38·69
1894	,,	,,	,,	68	,,	,,	38·87
1895	,,	,,	,,	69	,,	,,	52·91
1896	,,	,,	,,	56	,,	,,	59·85
1897	,,	,,	,,	54	,,	,,	39·67
1898	,,	,,	,,	66	,,	,,	48·85
1899	,,	,,	,,	63	,,	,,	47·50
1900	,,	,,	,,	64	,,	,,	36·95
1901	,,	,,	,,	65	,,	,,	57·61
1902	,,	,,	,,	71	,,	,,	58·80
1903	,,	,,	,,	68	,,	,,	43·68
1904	,,	,,	,,	70	,,	,,	37·01
1905	,,	,,	,,	68	,,	,,	31·40

The average rainfall for the thirty-two years, from 1874 to 1905, inclusive, was 45·57 inches, so that the rainfall for 1905 was 14·17 inches below the average.

DIAGRAM SHOWING AVERAGE RAINFALL IN ANTIGUA, 1874–1905.



RETURNS OF RAINFALL IN ANTIGUA FROM JANUARY 1, TO DECEMBER 31, 1905.

Names.	No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total.
Walling's (Dam)	1	3·94	2·30	3·62	2·91	1·66	3·14	4·20	7·90	4·02	3·45	4·70	3·01	44·85
Walling's (Hill)	2	3·99	2·03	3·35	3·41	1·54	2·56	4·63	8·34	3·75	4·16	4·05	2·74	44·55
Blubber Valley	3	2·53	1·87	3·11	1·80	1·63	3·10	4·41	7·15	3·51	5·03	5·03	2·84	42·01
Belle Vue	4	2·08	1·75	3·20	1·89	1·55	1·66	4·13	5·77	4·29	5·40	6·84	2·55	41·11
Delap's	5	1·77	1·60	2·67	1·52	1·33	2·45	3·51	5·69	4·51	3·63	6·19	2·82	37·69
Diamond	6	1·70	1·97	2·01	3·36	0·98	2·03	4·33	5·79	5·19	2·66	6·23	1·42	37·67
Big Duer's	7	0·98	2·00	1·56	2·55	1·00	2·09	3·97	6·69	4·91	3·50	6·98	1·21	37·44
Creek Side	8	1·19	1·18	1·86	1·76	0·86	1·66	3·50	6·41	6·59	4·80	4·71	2·46	36·98
Burke's	9	1·66	2·07	2·30	1·83	1·23	1·94	3·29	6·33	2·27	4·82	6·46	2·10	36·30
Bendal's	10	1·62	1·58	2·13	1·61	1·21	2·47	3·26	5·55	4·51	4·59	5·45	2·05	36·03
Orange Valley	11	2·06	1·08	1·52	2·06	1·17	1·55	2·74	8·22	4·11	3·96	4·11	2·85	35·43
Dimsdale	12	3·80	2·01	2·92	1·20	0·97	2·88	3·33	5·05	3·14	2·95	4·53	2·36	35·14
Green Castle	13	1·86	1·53	2·04	1·46	0·89	2·58	3·30	4·80	5·36	3·63	5·09	2·41	34·95
Pare's	14	1·55	1·51	1·43	2·65	1·15	1·90	3·38	5·38	5·58	3·25	5·42	1·63	34·83
Sanderson's	15	1·76	0·94	1·68	2·22	1·18	1·92	3·03	5·70	4·24	3·40	5·96	1·93	33·96
Parham Lodge	16	1·65	1·19	2·00	1·30	2·22	2·17	3·40	4·90	4·50	3·77	5·10	1·70	33·90
Lyon's	17	1·23	1·35	2·11	1·66	1·09	1·66	3·48	5·20	4·25	4·45	5·59	1·72	33·83
Betty's Hope...	18	1·57	1·58	1·73	2·95	1·08	1·51	3·46	4·94	5·59	2·63	5·35	1·43	33·82
Willis Freeman's	19	1·46	1·43	2·68	1·71	1·26	1·87	3·70	6·70	2·22	3·72	5·15	1·80	33·70
Donovan's	20	1·39	1·17	1·95	0·95	2·10	1·52	4·19	4·04	5·75	3·90	4·79	1·93	33·68
Ffrye's	21	1·52	1·54	2·04	1·46	1·03	1·62	3·54	5·82	3·44	3·80	5·97	1·79	33·57
Botanic Station	22	1·77	1·04	2·24	1·32	2·12	1·65	4·39	3·67	3·96	3·75	5·39	2·09	33·39
Lavington's	23	0·84	1·64	1·95	1·85	1·28	1·46	3·23	5·12	3·52	4·85	5·47	1·72	32·93

RETURNS OF RAINFALL IN ANTIGUA FROM JANUARY 1, TO DECEMBER 31, 1905.—(*Continued.*)

Names.	No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total.
Crosbie's	24	1·32	1·17	2·16	2·15	1·81	1·61	2·47	6·06	4·35	3·22	5·20	1·19	32·71
Otto's	25	1·48	0·76	1·88	1·15	1·37	1·38	4·08	4·18	5·22	3·41	5·69	1·95	32·55
Wood	26	2·55	1·88	2·99	1·60	2·52	1·56	3·09	4·94	3·88	2·68	3·64	1·23	32·56
Blake's	27	1·08	1·20	2·04	1·23	0·62	1·60	3·15	6·24	4·05	3·47	5·27	2·25	32·20
Parham New Work	28	1·78	0·99	1·54	1·39	1·68	1·48	3·67	5·48	4·30	3·08	4·69	1·70	31·78
Union	29	1·01	0·79	2·17	1·43	1·13	1·13	3·70	4·56	5·36	3·85	5·42	1·17	31·72
Montero's	30	1·56	0·92	1·88	1·04	0·53	2·04	3·63	5·16	3·81	3·26	6·01	1·87	31·71
Gaynor's	31	1·69	1·43	1·46	2·17	1·10	2·46	3·08	4·12	4·03	3·86	4·98	1·29	31·67
Morris Looby's	32	1·62	1·40	2·71	0·88	1·06	1·71	3·11	5·69	2·85	3·27	4·89	1·87	31·06
North Sound	33	0·94	1·16	1·70	0·98	1·13	1·62	3·34	4·89	5·90	3·52	4·19	1·57	30·94
McKinnon's	34	1·33	1·53	2·51	1·83	1·86	1·07	2·86	4·70	3·73	3·13	4·40	1·98	30·93
Langford's	35	1·39	0·82	2·16	1·89	1·42	1·12	2·20	6·07	3·97	3·56	4·77	1·53	30·90
Vernon's	36	1·65	1·17	1·54	1·31	1·60	1·52	3·73	4·92	4·98	3·26	3·88	1·30	30·86
Fitches Creek	37	1·42	1·12	1·42	1·18	0·98	1·42	3·40	3·72	6·47	3·76	4·25	1·47	30·61
Skerrett's	38	1·98	1·09	1·62	1·30	0·45	4·68*	0·00	4·31	4·03	3·83	5·04	1·93	30·26
Collon's	39	1·52	1·00	1·59	2·30	0·92	1·35	2·98	4·86	4·40	3·01	4·64	1·27	29·84
Belmont	40	0·61	0·61	1·71	1·23	1·31	1·47	3·92	4·79	3·37	3·31	5·40	1·88	29·61
Weatherill's	41	1·40	1·46	2·48	1·78	1·24	0·89	2·14	5·51	3·12	3·06	4·84	1·39	29·31
Montpelier	42	1·68	1·03	2·82	1·25	1·24	1·31	3·25	4·09	2·81	3·31	4·81	1·59	29·19
Hill House	43	1·43	0·91	2·85	1·55	0·90	1·81	2·85	4·93	2·34	2·74	4·82	1·96	29·09
Cochrane's and Thomas ...	44	1·21	1·64	2·06	1·21	0·80	1·60	3·19	5·37	2·65	3·28	4·62	1·43	29·06
Judge's	45	1·46	0·82	2·61	1·21	1·98	1·20	1·97	4·69	3·94	2·89	5·23	0·90	28·90
Comfort Hall	46	0·72	1·44	1·24	1·85	0·83	1·27	3·22	4·46	3·25	4·01	4·83	1·72	28·81

Skerrett's rainfall for two months, June and July, 4·68 inches.

RETURNS OF RAINFALL IN ANTIGUA FROM JANUARY 1, TO DECEMBER 31, 1905.—(*Concluded.*)

Names.	No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total.
Tomlinson's	47	0·86	0·90	1·81	0·97	1·38	1·12	3·95	4·20	3·65	3·59	4·61	1·77	28·81
Friar's Hill	48	1·69	1·52	2·63	1·98	1·44	1·37	2·44	4·10	3·17	2·40	4·34	1·61	28·69
Manning's	49	1·64	1·60	2·51	1·50	1·62	1·60	4·30	4·35	2·05	2·40	4·05	1·00	28·62
Carlisle's	50	1·58	1·24	2·08	1·50	1·72	1·17	1·41	3·31	3·91	4·16	4·25	2·27	28·60
Cedar Valley...	51	1·75	1·37	2·51	1·79	1·89	1·35	1·92	3·93	3·45	2·61	4·15	1·60	28·32
Cook's	52	1·50	1·15	1·30	1·45	0·40	0·51	2·95	5·02	4·74	2·70	4·70	1·90	28·32
Gamble's	53	1·13	1·13	2·26	1·24	1·04	1·38	2·92	3·27	3·78	2·65	4·82	2·44	28·06
Marble Hill	54	1·17	0·69	2·20	1·97	1·50	1·25	2·44	5·04	3·25	2·52	4·42	1·61	28·06
Parham Hill	55	1·18	0·90	1·40	1·79	1·04	1·22	3·21	4·08	5·06	2·70	4·01	1·31	27·90
Gilbert's	56	1·36	0·65	1·57	1·13	1·48	1·36	2·72	4·41	3·40	3·21	5·21	1·37	27·87
Millar's	57	1·45	1·03	1·97	1·24	1·56	1·71	1·26	3·20	3·76	4·29	4·23	1·72	27·42
Blackman's	58	1·04	0·46	1·61	0·92	1·42	1·07	2·80	3·49	4·66	3·52	4·18	1·76	26·93
Yepton's	59	1·07	0·92	2·17	1·00	0·90	1·28	3·24	3·52	3·88	2·86	4·28	1·63	26·75
Thibou Jarvis	60	1·18	0·58	2·09	1·62	1·34	1·18	2·15	4·51	3·07	3·05	4·38	1·06	26·21
High Point	61	1·06	0·88	2·40	0·90	1·40	1·58	1·30	3·51	3·70	3·96	4·86	0·63	26·18
Seaforth's	62	1·06	0·65	1·27	0·68	0·45	1·63	2·53	3·95	4·94	2·95	4·47	1·47	26·05
Cassada Garden	63	1·11	1·10	1·88	1·36	1·54	1·28	2·68	3·08	3·23	2·21	4·07	2·16	25·70
The Grove	64	0·64	1·18	1·36	0·39	0·53	1·18	3·22	3·70	4·73	3·71	2·97	1·91	25·52
Bobkin's	65	1·12	1·51	1·86	0·75	1·02	1·24	2·60	4·56	2·00	2·46	4·40	1·58	25·10
Cocoa-nut Hall	66	1·11	0·65	0·93	0·77	0·97	1·15	2·14	3·79	3·55	3·62	5·04	1·33	25·05
Mercer's Creek	67	0·89	0·45	1·24	1·29	1·25	1·23	2·75	3·50	3·10	3·00	4·09	1·31	24·10
Cotton	68	0·65	0·71	1·55	0·75	1·81	1·50	1·80	2·86	3·69	2·75	4·01	1·09	23·17
Codrington Village, Barbuda ...		1·25	1·36	1·30	1·32	1·26	1·35	1·81	3·90	4·50	4·88	2·11	1·77	26·81

METEOROLOGICAL SUMMARY, 1905.—KEPT AT THE GOVERNMENT LABORATORY, ST. JOHN'S, ANTIGUA

Month.	Thermometer. Dry. 9 a.m.	Thermometer. Dry. 3 p.m.	Thermometer. Wet. 9 a.m.	Thermometer. Wet. 3 p.m.	Dew Point. 9 a.m.	Dew Point. 3 p.m.	Maximum.	Minimum.	Barometer Corrected. 9 a.m.	Barometer Corrected. 3 p.m.	Wind. Miles run.	Wind. Average. Per day.	Wind. Average. Per hour.	Rainfall.	Barometer Corrected. Highest.	Barometer Corrected. Lowest.	Thermometer. Highest Max.	Thermometer. Lowest Min.
January ...	78·5	79·9	71·3	71·5	66·3	66·3	83·1	69·5	30·116	30·031	4,990	161·0	6·7	1·77	30·188	29·876	85	67
February	78·4	78·8	69·9	70·3	64·0	64·5	82·6	69·5	30·143	30·057	4,265	152·3	6·4	1·04	30·232	29·958	86	66
March ...	79·2	79·7	71·1	71·7	65·5	66·2	84·2	69·5	30·095	29·968	4,835*	210·2	8·7	2·24	30·167	29·922	87	67
April ...	80·9	82·3	73·7	74·2	65·5	68·8	85·2	72·1	30·090	30·001	...	...	...	1·32	30·168	29·945	90	68
May ...	81·8	82·8	74·5	74·6	69·5	69·2	85·8	72·8	30·084	30·020	2,330	211·8	8·8	2·12	30·145	29·942	89	70
June ...	83·8	84·3	75·9	76·2	70·7	70·7	87·2	74·8	30·072	30·027	6,300	210·0	8·9	1·65	30·160	29·958	89	71
July ...	84·1	84·4	76·5	76·6	71·6	71·5	86·8	74·9	30·094	30·048	6,645	214·3	9·0	4·39	30·145	29·995	89	71
August ...	84·1	85·9	77·4	76·9	73·0	71·1	87·4	75·1	30·075	30·016	6,275	202·4	8·4	3·67	30·101	29·983	90	65
September	84·4	85·4	77·0	77·3	72·2	72·1	88·5	74·0	30·012	29·951	4,700	156·7	6·5	3·96	30·094	29·872	92	64
October ...	83·6	83·2	78·4	77·6	74·7	73·6	88·4	73·9	29·995	29·911	3,745	124·8	5·0	3·75	30·102	29·836	92	67
November	82·4	83·5	75·1	75·4	70·5	70·4	86·0	72·0	30·012	29·932	3,795	126·5	5·3	5·39	30·098	29·838	89	69
December	83·9	81·8	73·5	73·2	68·7	68·1	85·0	71·7	30·084	30·006	3,465	208·5	8·3	2·09	30·172	29·914	89	70
											54,345			33·39				
Means for year ...	82·1	82·7	74·5	74·6	69·4	69·4	84·9	72·5	30·073	29·999	4,529	148·9	6·2	2·80				

* March. Anemometer worked for twenty-three days. April.—Anemometer not working. May.—Anemometer worked for eleven days.

Highest maximum, 92° on September 26 and 27, October 12.

Lowest minimum, 64° on September 7.

Highest barometer corrected, 30·232 on February 20.

Lowest barometer corrected, 29·836 on October 31.

Greatest rainfall in twenty-four hours, 1·35 inches on August 20.

Greatest number of miles run by wind in twenty-four hours was 335 on January 18.

Earthquakes recorded, two: on February 15 and March 30, both slight.

CYCLONIC DISTURBANCE NORTH OF ANTIGUA.

The following memorandum on meteorological conditions observed during the cyclonic disturbance which passed to the north of Antigua August 31–September 1, 1906, has been forwarded for publication by Mr. H. A. Tempany, B.Sc., F.I.C., Acting Government Chemist for the Leeward Islands :—

On August 31–September 1, a cyclonic disturbance passed to the north of Antigua. The first indications of the existence of cyclonic conditions were obtained on Monday, August 27, when the usual 3 p.m. barometer reading was found to be abnormally high, higher in fact than the morning reading of the same day.

This elevated condition of the barometer continued during Tuesday and Wednesday, and on this account a sharp look-out was maintained during these and the following days. On Thursday afternoon the barometer began to fall, and by Friday morning the fall had become sufficiently marked to indicate that the disturbance was approaching Antigua.

During Friday a sharp look-out was maintained, and frequent readings of the barometer were taken.

By mid-day Friday it was concluded, from observation of the sky conditions, that the disturbance was in all probability an old one of wide area and comparatively moderate wind velocity. The borometer continued to fall steadily during Friday, and at 6 p.m. it was found possible, from the direction of the wind and the movements of the low clouds, to localize the centre of the disturbance as ESE–E of Antigua.

By 8 p.m. the fact that there was no tendency on the part of the barometer to accelerate its fall, and the tendency of the wind to shift to the NW, with no immediate increase of velocity, rendered it apparent that the disturbance would pass to the north, and that no great danger need be apprehended.

By 9 a.m. Saturday morning the wind was blowing NW and between that time and 12.30 p.m. had shifted round to SW.

The disturbance passed north of Antigua between 10.30 and 11.30 a.m. on Saturday, September 1.

The barometer reading at 9 a.m. on Saturday was 29·77 inches and it continued to fall till 3 p.m., when the reading recorded was 29·69 inches, this being the lowest for seven years.

The fact that the barometer continued to fall after the centre had passed was due to the usual daily drop between morning and afternoon; allowing for this, the pressure remained fairly constant between 9 a.m. and 3 p.m. From that time onward, the barometer gradually rose; the rise continued over the whole of Sunday and Monday, normal barometric conditions not being attained till Tuesday afternoon. The passing of the centre of the disturbance was followed by increased wind velocity and much rain.

The maximum wind velocity attained would probably be about 60 miles an hour; the actual number of miles run by the wind in the twenty-four hours between 12 a.m. on Saturday, September 1, and 12 a.m. on Sunday, September 2, was 975, with an average velocity of 40·6 miles per hour.

The actual path of the disturbance lay to the north of Barbuda, and thence north of St. Kitt's, near St. Eustatius and Saba.

The barometer readings taken on Friday, with observations on the weather at the time of taking the readings, are given below, together with the rainfall at the Botanic Station, and the wind velocity at Skerrett's for twenty-four hours.

Thanks are due to Mr. J. Goodwin, of the Antigua Station of the West India and Panama Telegraph Company, for the extremely courteous and useful assistance rendered by him in obtaining readings of the barometer, and observations of the weather in neighbouring islands at the time of the passing of the disturbance.

Date.	Wind at Skerrett's. Miles in 24 hours.	Average per hour.	Rainfall at Botanic Station.
Friday, August 31 ..	325	13·5	0·46 inches.
Saturday, September 1	975	40·6	5·92 ,,
Sunday ,, 2	325	13·5	0·93 ..

Barometer Readings during passing of Cyclonic Disturbance on August 31–September 1.

FRIDAY, AUGUST 31.

Time.	Barometer reading.	Wind.	Remarks.
	Inches.		
9.0 a.m.	29·98	ENE–N.	Wind gusty.
12 noon.	29·96	,, ,,	,, ,,
1.30 p.m.	29·94	,, ,,	,, ,,
3.0 ,,	29·92	,, ,,	,, ,,
4.30 ,,	29·86	,, ,,	,, ,,
6.0 ,,	29·86*	,, ,,	Clouds moving NE—ENE.
8·0 ,,	29·86*	N-NW	Centre ESE Antigua.
12 mnt.	29·84*	,, ,,	Calmer with occasional rain.

SATURDAY, SEPTEMBER 1.

Time.	Barometer reading.	Wind.	Remarks.
	Inches.		
9.0 a.m.	29·77	NW	Squally with increasing
10.30 ,,	29·75	W	wind and rain.
12.30 p.m.	29·72	SW	Cyclone passing N. of
2.30 ,,	29·69	,,	Antigua.
4.0 ,,	29·70*	SSW–S	Wind and rain.
6.30 ,,	29·74*	,,	,, ,,
8.0 ,,	29·82*	,,	,, ,,
9.0 ,,	29·84*	,,	Lightning to S. and W. Very gusty; much rain.
10.30 ,,	28·93*		Calmer.

* These readings were taken on a small and sensitive aneroid, in close agreement with the mercurial barometer on which the remaining readings were taken.

RAINFALL OF ST. CROIX IN RELATION TO SUGAR CROPS.

In connexion with the foregoing papers in reference to the meteorology of Antigua, it may be interesting to publish the following information regarding the rainfall of the neighbouring island of St. Croix in relation to the island's sugar-cane crops. This article was contributed to the St. Croix *Avis*, of September 1, 1906, by Mr. J. P. Jörgensen :—

As long as St. Croix exists, the old toast 'more rain for St. Croix' will likely continually be given. And there is no doubt that plenty of rain brings good crops. But I have often noticed that it is not always that the most rain gives the greatest crop. This has puzzled me, and in studying and comparing the crops in St Croix from 1891 to 1902 and the rainfall from 1890 to 1901, which data have lately been published, I have tried to find the causes why more rain did not always give a larger crop. I do not know if I have found the causes, but it may be that some one else is able to do it, and I therefore now publish the data, viz. :—

RAINFALL AND SUGAR CROPS OF ST. CROIX FOR THE YEARS 1890 TO 1901.

Arranged according to the rainfall.					Arranged according to the crop.				
Rainfall.			Crops.		Crops.		Rainfall.		
Year.	The whole year.	April 1 to June 30.	Year.	Hogsheads.	Year.	Hogsheads.	Year.	The whole year.	April 1 to June 30.
	Inches.	Inches.						Inches.	Inches.
1901	45·91	27·43	1902	21,250	1902	21,250	1901	45·91	27·43
1896	38·43	23·27	1897	19,552	1899	20,743	1898	34·62	22·75
1893	38·42	27·31	1894	20,227	1894	20,227	1893	38·42	27·31
1895	38·27	19·70	1896	18,352	1901	20,147	1900	31·18	19·07
1897	37·62	22·96	1898	16,863	1897	19,552	1896	38·43	23·27
1898	34·62	22·75	1899	20,743	1896	18,352	1895	38·27	19·70
1891	34·56	17·19	1892	15,488	1898	16,863	1897	37·62	22·96
1900	31·18	19·07	1901	20,147	1892	15,488	1891	34·56	17·19
1894	30·21	14·65	1895	13,580	1895	13,580	1894	30·21	14·65
1892	24·14	15·29	1893	10,220	1900	11,485	1899	23·41	12·74
1899	23·41	12·74	1900	11.485	1893	10,220	1892	24·14	15·29
1890	20·81	8·10	1891	3,367	1891	3,367	1890	20·81	8·10

More Detailed Information.

Crops.		Rainfall.								
Year.	Hogsheads.	Year.	Total amount.	April 1 to September 30.	January 1 to March 31.	April 1 to June 30.	July 1 to September 30.	October 1 to December 31.	Year.	January 1 to March 31.
			Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.
1902	21,250	1901	45·91	27·43	5·44	6·74	20·69	13·89	1902	4·99
1899	20,743	1898	34·62	22·75	2·61	7·21	15·54	9·26	1899	2·25
1894	20.227	1893	38·42	27·31	4·99	12·81	14·50	6·11	1894	3·14
1901	20,147	1900	31·18	19·07	3·21	10·51	8·56	8·89	1901	5·44
1897	19,552	1896	38·43	23·27	4·12	8·55	14·72	11·01	1897	3·88
1896	18.352	1895	38·27	19·70	2·73	7·94	11·76	15·84	1896	4·12
1898	16.863	1897	37·62	22·96	3·88	15·63	7·33	10·89	1898	2·61
1892	15,488	1891	34·56	17·19	2·35	6·78	10·41	15·01	1892	2·34
1895	13.580	1894	30·21	14·65	3·14	7·44	7·20	12·42	1895	2·73
1900	11,485	1899	23·41	12·74	2·25	4·96	7·78	8·41	1900	3·21
1893	10,220	1892	24·14	15·29	2·34	8·11	7·18	6·34	1893	4·99
1891	3,367	1890	20·81	8·10	5·94	2·67	5·43	6·76	1891	2·35

If we compare, for instance, the rainfall in 1895 and 1897, it will be seen that it is about the same (38·28 inches against 37·62), but the small difference causes the crop in 1898 of 16,863 hogsheads to increase to 18,352 in 1896. This practically contradicts the rule, that more rain gives a larger crop. And if we compare the rain of 1897 and 1898 (37·62 inches and 34·62), also nearly the same, we find that the crops in 1898 were 16,863 hogsheads and 20,743 hogsheads in 1899. Here is a very great difference in the crops, and it is the smaller rainfall which gives the larger crop. Now this is bewildering. As bewildering it is, if we compare the years 1898 and 1901, with exactly the same amount of rain (34·62 against 34·56), while the crops in 1899 were 20,743 hogsheads and in 1892 only 15,488 hogsheads. But the most bewildering comparison is the year 1891 with 34·62 inches of rain against 1900 with only 31·18 inches, a very great difference especially as 31·18 inches is below the average: but in 1901 the crop was 20,147 hogsheads and in 1892 only 15,488, also a very great difference, but in favour of the smaller rainfall, which, in fact, brought one of the greatest crops St. Croix has had.

Where is the secret? If we look carefully into the data given above, it appears that the rainfall in the months April to September, and especially in the months July, August, and September, is the deciding feature in regard to the growing crop. There are only a couple of exceptions from the rule, and the most glaring is the year 1900 with the small rainfall (even small in July, August, and September) and the large crops in 1901. But the year 1900 must have been a most extraordinary year. The rain, small as it was, seems to have fallen exactly when it should. Only one month was really dry, viz., February (0·67 inch).

By comparing the rainfall in 1891 (34·56) and the crop in 1892 (15,488 hogsheads) with the rainfall in 1900 (31·18 inches) and the crop in 1901 (20,147 hogsheads), it appears that the rain in 1891 fell very irregularly. In January the rain was only half, in March only a fifth, and in May only a third of the average. This must have almost ruined the growing crop: and that the total rainfall became so large, in spite of the previous drought, was caused by a very heavy rainfall in October (9·92 inches). This rain came too late to produce a good crop, but evidently in time to turn a very bad outlook into a decent crop.

It is natural that the smallest rainfall (1890 with 20·81 inches) should produce the smallest crop (1891 with 3,367 hogsheads). But when the crop became such a total failure, it is evident that it was because there only fell 2·67 inches in April to June and 5·43 inches in July to September (in all, 8·10 inches), while much more rain fell in January to March (5·94 inches), which is extraordinarily high, and in October to December (6·76 inches), in all, 12·71 inches; consequently, at the time of the year when it does not do so much good.

I now hope that some one will clear up the matter fully. My conclusions are:—

(1) Good rainfall, distributed evenly, gives the greatest crop.

(2) A smaller amount of rain falling evenly gives a larger crop than more rain falling unevenly.

(3) The rainfall in July, August, and September decides the crop of the next year, whenever the canes are in a healthy state at the end of June.

(4) The very heavy rainfalls are, of course, welcome: but cannot, late in the year, make up for dry weather earlier.

(5) The rain falling in January to March, the same year the crop is taken off, seems not to have any influence.

SOME IMPERIAL ASPECTS OF APPLIED CHEMISTRY.

The following is the opening address, as reported in *Nature* (August 9, 1906), by Professor Wyndham R. Dunstan, M.A., LL.D., F.R.S., President of the Chemical Section of the British Association, at the meeting of the Association recently held at York. Dr. Dunstan's address contains much that is of interest in connexion with tropical agriculture :—

The President of the Chemical Section of the British Association must always have a large choice of subjects for his address. He may attempt to review the chemical progress of the year, or to give an account of researches in that division of the science in which he is most interested. He may deal with the ever-recurring problems of education; or, again, he may draw attention to the importance of our science in one or other of its many relations to national and imperial affairs. I have decided to adopt the last course, and to invite your attention at York, where several tropical products furnish the basis of important industries, to the intimate connexion of our science with the problems that await solution in connexion with the utilization of the raw materials and economic products of our colonies, and especially those of our tropical possessions. There is a pressing need that the Imperial Government should recognize much more fully than it has hitherto done, and at least as fully as foreign Governments are already doing, the claims of scientific investigation to be regarded as the pioneer instrument of this work, and as the essential first step in the material and commercial development of our possessions.

Although my remarks will be chiefly directed to the importance of chemistry in this connexion, my plea will be more general. It is that the scientific method of experimental research should be systematically applied in each division of the sciences concerned. In the case of raw materials, however, whether vegetable or mineral, their commercial value must depend chiefly, if not entirely, upon their composition, and sooner or later the method of chemistry must therefore be applied.

In determining the value of the mineral resources of a country, other specialists are also concerned, and the assistance of the geologist, and the mineralogist, and eventually of the metallurgist may be required. Similarly with vegetable and agricultural products, the services of the economic botanist and of the entomologist will be needed. It will therefore be necessary for me, in dealing with the subject as a whole, to touch upon several aspects in which other sciences are concerned, and with which the science of chemistry must co-operate in attaining a practical end—namely, the material development of the countries concerned. I need make no apology for many allusions to scientific agriculture, for this subject is this year attached to this section, and indeed the science of chemistry is of fundamental importance to agricultural practice both at home and in the tropics.

In the first place I must ask you to allow me to say a few words as to the very wide interests that are involved in the proper solution of the problem of colonial development.

It is all-important that the wage-earning community of this country should have an adequate supply of tea, coffee, cacao, rice, tobacco, and other commodities, and that our manufacturers should be able to count upon a regular supply of cotton, jute, rubber, and other raw materials as far as possible under their own control. All these products are derived almost exclusively from the tropics, and experience shows that it is a great disadvantage to the manufacturer not to be able to exercise control in the direction of securing the regular production of these materials, and especially not to be able to avoid the great and sudden fluctuations in their price, which are often the result of financial speculation on the part of a foreign capitalist who has secured the control of the output of a foreign country.

The almost entire dependence of the great textile industries of Lancashire upon the cotton crop of the southern states of America has placed this industry at the mercy of American speculators, whose tactics may lead, as in 1903, to such a rise in the price of the raw material as to render it imperative for the manufacturer to close his mills, and, by throwing large numbers out of employment, to bring poverty and misery to many thousands of people.

The great principle which must now necessarily guide our system of administration and expenditure in our tropical colonies and protectorates has as its purpose the utilization of natural resources and the creation and development of native industries with the aid of European supervision and advice. Adequate supplies of produce, natural and agricultural, will thus be ensured to British manufacturers and consumers from territories within the administration of the British Crown. This principle of employing our 'undeveloped estates' for the advantage of our manufacturers and consumers, and at the same time for the benefit of the natives who inhabit these countries, was put into action by Mr Chamberlain during his long tenure of office as Secretary of State for the Colonies, and this recognition of a vitally important principle must always be associated with his name.

Excepting India and the self-governing colonies, the Crown colonies and protectorates, for which alone the Imperial Government is directly responsible, include an area of about two and a half million square miles and a population of about forty millions. The value of these possessions to us at the present time may be judged from the value of their import and export trade with the United Kingdom. The value of the exports of these countries in 1904 was estimated at about four and a half million pounds sterling, and the imports from the United Kingdom at about twelve and a half million pounds sterling. In gauging the importance to this country of the development of these possessions, the export trade of which is only in its infancy, it should be remembered that the profits arising from the export as well as from the import trade are chiefly domiciled in this country; since practically the whole of this trade is in the hands of British merchants, and the entire profits, including those of shipping, etc., are therefore subject to our national system of taxation, and represent a very substantial annual contribution to the British exchequer.

It is therefore only reasonable that a certain sum should be expended from British funds to aid the applications of science to the commercial development of these possessions. Such an expenditure, in the light of the facts to which I have drawn attention, may be regarded as an investment with the certainty of a profitable return.

I have thought it necessary to give this brief account of the position of our still undeveloped Crown colonies and protectorates, and the national importance to us of their systematic development before proceeding to the principal subject of this address, which is to emphasize the aid which science in several of its branches can render to this work of development, and especially the science of chemistry, the capacities of which in this connexion have so far not been sufficiently recognized.

The importance of utilizing our own tropical possessions as sources of the raw material required by the manufacturer is now generally recognized, and very considerable progress has been made in recent years. The tea produced in India and Ceylon has largely superseded the China tea formerly used in this country. Similarly, coffee is extensively grown in India and the West Indies, and in several of our African possessions. The jute cultivation in India has been very successful, and the demand for this fibre is so great that the question of its cultivation in our West African Colonies is now under consideration. India-rubber, hitherto chiefly obtained from South America, is of increasing importance as a commercial article, and the South American tree has been introduced with success in Ceylon, the Straits Settlements, and the Federated Malay States, which are rapidly becoming important rubber-producing countries, the produce of which is competing successfully with that of South America. The cultivation of cotton, hitherto principally carried on in the United States, is being vigorously proceeded with in India, the West Indies, and in West Africa, as well as in Egypt and the Soudan, and we may

look forward in the future to these countries supplying the British manufacturer with a large proportion, if not the whole, of the cotton he requires.

There are, however, vast resources, both mineral and vegetable, in our colonies and protectorates which are awaiting development for an exact knowledge of their composition and properties, which can only be ascertained by scientific means and chiefly through chemical investigation, whilst the British manufacturer is in need of increased and better supplies of the raw materials on which his industrial activity depend. This demand for increased supplies now affects nearly every industry in this country. Rubber and fibres are well-known examples; oils and fats for the manufacture of soap and perfumes; and tanning materials, as well as numerous minerals, are other instances in which our manufacturers are at present anxious to discover new sources of supply. These sources can only be discovered and their value ascertained by properly directed scientific investigations.

We have heard much recently respecting the assistance which science can bring to the maintenance and development of the industrial efficiency of this country, and the Imperial Government is being urged to give its help especially by providing increased facilities for the education of scientific men, competent to aid the manufacturers of this country in improving their methods and processes. In this work the science of chemistry is one of the most important. There is scarcely an industry to which it is not able to render immense service. Within recent years this fact has slowly gained recognition, and the principle of state assistance to industry is virtually admitted, both in respect of education and of research. The most recent examples of a recognition of the principle are the grants made from the national treasury to the new Technological College at South Kensington, and to the National Physical Laboratory.

Not less important than the service which science can render to existing industries and their extension is that which it can contribute to the imperial problem of ascertaining and rendering available for the manufacturer the vast undeveloped resources of our own possessions. Our own experience and the example of other countries have shown that such work cannot be systematically carried on by private enterprise. Upon its successful accomplishment depends, not only the unrestricted supply of the necessary raw materials for which the manufacturer looks in increasing quantity, but also the prosperity of the country which produces these materials. This success can be brought about only by a combined effort on the part of the manufacturer and of the Government. The manufacturer can provide information as to the materials he needs. The preliminary work of discovering suitable material by scientific means, as several foreign Governments have already recognized, must be endowed, directed, and carried on with Imperial funds. It cannot be expected that private enterprise will take steps to explore the resources of little-known countries on the chance of a particular material being discovered, nor can the work, as a rule, be successfully done by

this means. Experience shows that the most effective manner of promoting the commercial development of a new country is for the Government to carry out systematically, with its own officers, the preliminary work of exploration and examination of the natural resources, with the aid of such technical advice as may be necessary from manufacturers and users, and then, having established the fact that particular products of value can be found or cultivated in a given country, to leave commercial enterprise to do the rest. By action on these lines immense progress is being made in French, German, and Dutch possessions, whilst the United States Government has taken similar action with the Philippines. In our own case, where this work exists, it is in most cases in a more or less embryonic condition, and lacks the organization which is necessary for success.

In many of our Crown colonies and protectorates there already exist, or are in the process of organization, agricultural and other scientific departments, many of which include officers who are engaged in the work of exploring and developing the vegetable resources of these countries, especially by experimental planting. Chemists are attached to some, but not to all of these departments. In the West Indies the valuable work accomplished by Professor Harrison, Dr. Francis Watts, Professor d'Albuquerque, Professor Carmody, and Mr. Cousins is well known and illustrates the great services which the science of chemistry may render, not only to tropical agriculture, but to every branch of economic development. It is clearly desirable that at least one scientific department should be attached to the Government of each of the principal Crown colonies and protectorates. As a rule, it is convenient that this should be an agricultural department with the services of a scientific chemist at its disposal. In a tropical climate, and with limited appliances at his command, it must be admitted that a chemist is severely handicapped, and, as a rule, he cannot be expected at first to be able to do much beyond the comparatively simple and preliminary work, chiefly analytical, which, however, in a little-known country, is of the greatest importance to an agricultural department. In addition he would have to deal with the composition of natural products of all kinds, both vegetable and mineral, as well as with the improvement of native industries. If the chemist is able to refer complicated or special investigations to a central department at home and is provided with assistance in the routine work, he would be in a position to undertake the scientific investigation of a selection from the numerous problems with which a chemist will be confronted.

A chemist, working in the spirit of an investigator, will be able to render special services to the cause of tropical agriculture, and it is therefore of importance that in future the men appointed to these posts should be chosen as far as possible on account of the promise they have shown as investigators. The determination of the constituents of little-known indigenous plants, as the first step towards ascertaining their economic value, is another department of work which cannot be carried out without a chemist, and the same applies to the examination

of poisonous plants, and also of minerals, in addition to the determination of the composition of foods and feeding stuffs.

Tropical agriculture is a subject which is now of the first importance, especially in those countries in which our policy is to depend on a native population for the actual cultivation of the soil. We have two functions to perform in our position as supervisors: the one is to ascertain the nature and capabilities of the soil by actual experiment, for which well-organized experimental stations are a necessary part of every agricultural department; the other duty is to convey to the natives, chiefly by means of demonstration, the results of this experimental work, so that they may be persuaded to make it a part of their agricultural practice.

Work on these lines is being done under Government auspices in the French and German colonies, and I may allude to the French successes in Algeria, in Senegal, and in the Soudan, and to the advances made by Germany in East Africa. These achievements are mainly due to a policy of continuous scientific work on agricultural lines. We shall have the privilege of hearing from Dr. Greshoff, the eminent Director of the Colonial Museum at Haarlem, an account of the chemical investigations which are being carried out in connexion with Java and the Dutch East Indies.

In many of our own colonies and protectorates active agricultural departments, equipped with the means of experimental working, are only now in process of organization. One of the most recently organized of these is that of the Transvaal, which, at Lord Milner's initiation, has been completely equipped on the lines of that model for all such effort, the Agricultural Department of the United States. This department has as its chief chemist Mr. Herbert Ingle, of the Yorkshire College, now the University of Leeds.

If we are to compete successfully with foreign countries, it is necessary that the position of science in relation to tropical agriculture should be definitely recognized. The days when a botanical garden served the purpose of an entire scientific establishment in a colony have passed away, and we now require, in order that a proper return should be obtained, and the natives assisted in their agricultural practice, a scientific department with a proper complement of specially trained officers, including a consulting chemist, other specialists being added to the staff as the requirements arise. These officers should be remunerated on a scale likely to attract some of the best-educated men from this country, which is at present far from being the case.

It would be out of place to discuss here the detailed organizations of these scientific departments. I merely desire to urge the necessity of their functions being extended, and of their receiving adequate financial support.

It is important that the scientific work which is being accomplished by these various departments should be brought to a focus, and that the results obtained in one colony should be available for the information of the departments in other colonies. The work of all such establishments requires to be

unified by co-operation with a central department which can extend the investigations conducted in the colonies, carry out investigations and inquiries which cannot be undertaken on the spot, maintain the necessary touch with the manufacturers, and co-ordinate the work undertaken and the results obtained in each of the separate colonial establishments and systematically collate it, so that each may be aware of the results that are being obtained in other countries. In our African possessions at present the same investigations and inquiries have to be conducted independently, and often without the knowledge that the problem in question has been already solved.

Another increasingly urgent duty of the central department is to inform the colonial establishments of the results of the work which is being conducted in foreign countries, and of the progress which is being made in the utilization of raw materials all over the world, and to bring to their notice the constantly changing requirements of the manufacturers and users of raw materials.

So far as botany is concerned, this co-ordination has been to a large extent effected through the agency of the Royal Gardens, Kew, which are in touch, through the Colonial Office, with all the botanical gardens in the Crown colonies and protectorates. In chemistry, as well as in certain other subjects, these duties have been performed in recent years by the Scientific and Technical Department of the Imperial Institute, which is now working in co-operation, not only with the Governments of the Crown colonies and protectorates, but also with those of several of the self-governing colonies and also with the scientific departments which have been brought into existence in India, where, at last, the importance of scientific agriculture is receiving due recognition from the Government.

So little has hitherto been done in this direction that the number of problems requiring attention is exceedingly large; and even with a specially trained staff of workers and extensive laboratories, such as now exist at the Imperial Institute, it becomes necessary to select, as the principal subjects for investigation, those which are regarded by the Governments of the countries concerned as of the most practical importance, and in which the British manufacturer is at the moment most concerned. There must therefore remain a large number of materials of unknown composition and of problems of purely scientific interest, which offer an attractive field for the chemical investigator. Already steps have been taken to provide for the investigation of these subjects by scientific men who are willing to undertake them in communication with the Institute. For example, Mr. A. G. Perkin, F.R.S., has been furnished with material which has led to the identification and determination of the constitution of the colouring matters of a number of plants which are employed as dyes in India and the colonies. Professor A. H. Church, F.R.S., has determined the composition of many new or little-known food grains. Dr. Crossley, Mr. Le Suer, and Dr. Lewkowitsch have examined the constituents of a large number of fats and oils

furnished by seeds of Indian and African origin. Dr. W. J. Russel, F.R.S., has been furnished with selected materials for examination in connexion with his interesting investigations of those substances which affect the photographic plate in the dark, while the Hon. R. J. Strutt. F.R.S., has investigated the radio-activity of a number of new or little-known minerals containing rare earths. Last year more than 500 different materials and problems were submitted from the colonies and India for investigation to the Scientific Department of the Imperial Institute, and each year there must remain an increasing number of interesting subjects which cannot be included in the Department's annual programme of work. Many of these would furnish excellent subjects for chemical research by advanced students in connexion with the universities and technical colleges throughout the country. It is nearly always possible to arrange to furnish the necessary material for any competent worker to deal with. Next year a list of such subjects awaiting investigation will be available at the Imperial Institute for those in search of subjects for chemical research.

Whilst the investigation of some of these subjects may at once produce results of scientific value, many of them present difficulties in their investigation which are far more serious than those which attend the usual synthetical work in organic chemistry. I do not know of any more profitable experience for the advanced student, who is already familiar with the principles of organic chemistry and of laboratory practice, than the separation in the pure state of the chemical constituents of a plant and the determination of their chemical constitution. In inorganic chemistry the examination of a new mineral furnishes similar experience.

In carrying out research of the kind I am advocating, the chemical investigator will have the additional advantage of knowing that the scientific results he obtains will contribute to the knowledge of the resources of the British Empire, and possibly be the means of laying the foundations of new industries.

I need hardly remind chemists that some of the most important discoveries in our science, and many of those which have had the most profound influence on the development of chemical theory, have arisen from the examination of the constituents of raw materials. The discovery of morphia in opium led to the recognition of the new class of alkaloids; the discovery of amygdalin in the bitter almond of the new group of glucosides; the investigation by Liebig and Wöhler of the chemical properties and composition of the essential oil of the bitter almond was largely instrumental in laying the foundations of modern organic chemistry; whilst it was during the examination of the constituents of bran that Fownes was led to the discovery of furfurol and the subsequent recognition of a new type of organic compound. In more recent times the examination of the constituents of oil of turpentine and various essential oils yielded by different plants has been the means of elucidating the chemical theory of the great group of

terpenes, and latterly Harries' investigation of caoutchouc has led to the discovery of the ozonides which seem likely to be of much importance as a new means of determining the constitution of certain classes of organic compounds. Lastly, I may remind you that the discovery of helium might have been long delayed had not Professor Miers drawn Sir William Ramsay's attention to the so-called nitrogen furnished by the mineral cleveite.

I have thought that it would be of interest on the present occasion if some account were given in the section of chemistry of certain of the raw materials employed in the principal manufacturing industries of the city of York. These industries are vitally concerned with an adequate supply of certain raw products of tropical origin, especially cacao and gums. In connexion with the first of these, which has hitherto been obtained chiefly from the West Indies, a new industry of cacao production has sprung up in West Africa, notably in the Gold Coast and in Lagos. This West African cacao presents some peculiarities which have rendered it desirable to examine the nature of its constituents. Gums of the nature of gum arabic are at present chiefly derived from the French colony of Senegal. It is, however, clear from the examination of gum collected in West Africa that that country, and especially Northern Nigeria, will be able in the future to contribute to the needs of the British manufacturer, in addition to the Soudan, India, and Australia, which will also be able to make important contributions. In connexion with the investigation of these gums derived from new sources at the Imperial Institute, the very remarkable observation has been made that certain gums from India and the colonies possess the property of evolving acetic acid when exposed to the air. The chemical constitution of one of these gums has been fully investigated at the Imperial Institute by Mr. H. H. Robinson, who will contribute a paper on the subject to the section, in which he will show that the production of acetic acid is due to the elimination of an acetyl group by hydrolysis through the moisture of the air. He has also succeeded in elucidating to a large extent the chemical nature of the gum. Mr. Robinson will also make a report on the present position of the chemistry of gums, a class of substances the constitution of which is exceptionally difficult to unravel. Little, if any, advance has been made in recent years on the well-known researches of O'Sullivan.

There is no more important group of questions demanding attention from the chemist at the present time than those connected with the production of India-rubber or caoutchouc. An enormous increase in the demand for India-rubber has taken place in the last few years, and last year the production was not less than 60,000 tons. Until recently the supply of rubber came chiefly from two sources—the forests of Brazil, which contain the tree known as *Hevea brasiliensis*, furnishing the Para rubber of commerce, which commands the highest price, and the forests of Africa, where climbing plants, generally of the *Landolphia* class, also furnish rubber. The increased demand for caoutchouc has led to the extensive planting of

the Para rubber tree, especially in Ceylon and in the Federated Malay States. Systematic cultivation and improved methods of preparation are responsible for the fact that the product of the cultivated tree, which begins to furnish satisfactory rubber when six or seven years old, is now commanding a higher price than the product of the wild tree in Brazil. It is estimated that within the next seven years the exports of cultivated India-rubber from Ceylon and the Federated Malay States will reach between ten and fifteen million pounds annually, and that after fifteen years they may exceed the exports of the so-called wild rubber from Brazil.

The services which chemistry can render to the elucidation of the problems of rubber production and utilization are very numerous. Methods of treatment depending on a knowledge of the other constituents of the latex have led to the production of rubber in a purer condition. Much still remains to be elucidated by chemical means as to the nature of the remarkable coagulation of the latex. As is well known, the latex is a watery fluid, resembling milk in appearance, which contains the rubber, or, as I think more probable, the immediate precursor of rubber, together with proteids and other minor constituents. The constituent furnishing rubber is in suspension, and rises like cream when the latex is at rest. On the addition of an acid, or sometimes of alkali, or even on mere exposure, coagulation takes place and the rubber separates as a solid, the other constituents for the most part remaining dissolved in the aqueous liquid or 'serum.' The first view taken of the nature of the coagulation process was that, like the coagulation of milk by acids, it is dependent upon a process of proteid coagulation, the separated proteids carrying down the rubber during precipitation.

This explanation cannot, however, be considered complete by the chemist, and there are peculiarities connected with the coagulation of the latex which are opposed to the view that it is wholly explained by the coagulation of the associated proteids. The experimental investigation of the question on the chemical side is beset with many difficulties, which are increased if access cannot be had to fresh latex. A number of experiments were made at the Imperial Institute with latex forwarded from India. The difficulties contended with in preventing coagulation during transit were great, but, in the case of the latex derived from certain plants, these were to some extent surmounted, and the results obtained, especially with reference to the behaviour of certain solvents towards the latex, led to the conclusion that 'coagulation' can take place after removal of the proteids, and that in all probability it is the result of the polymerization of a liquid which is held in suspension in the latex and on polymerization changes into the solid colloid which we know as caoutchouc. Weber, by experiments conducted in South America with fresh latex, arrived at a similar conclusion, which later workers have confirmed. Although the nature of the process is not yet completely elucidated, there is little room for doubt that the coagulation is due to the polymerization of a liquid and possibly of a liquid hydrocarbon contained in the latex. For the chemist

the important question remains as to the nature of this liquid from which caoutchouc is formed.

The chemical nature of caoutchouc is a subject which has attracted the attention of distinguished chemists from the middle of the eighteenth century, among them being Faraday, Liebig, and Dalton. Faraday was the first to examine the constituents of the latex of *Hevea brasiliensis.* It is only in recent years that our knowledge of the constitution of organic compounds, and especially of the terpene group, has rendered it possible to make any great advance. It is interesting to record that Greville Williams, in 1860, made most important contributions to this subject. He identified a new hydrocarbon, isoprene, as a decomposition product of caoutchouc, and recognized its polymeric relation to caoutchouc.

The results obtained from the analytical side, and especially the formation of di-pentene and isoprene by pyrogenic decomposition of caoutchouc, had pointed to the fact that caoutchouc was essentially a terpenoid polymer of the formula $C_{10} H_{16}$. Harries finds, however, that the ozonide of caoutchouc, when distilled with steam, breaks up into lævulinic aldehyde, lævulinic acid, and hydrogen peroxide, and he concludes from this that caoutchouc is a polymer of a 1 : 5 dimethyl cyclo octadien. Whilst Harries' work has brought us much nearer the goal, and has led to the discovery of a new method of investigation through the ozonides, which is obviously of wide application, it cannot yet be said that the constitution of caoutchouc has been settled or its relation to the parent substance of the latex definitely established. It has still to be shown how a closed-chain hydrocarbon, such as Harries' octadien, can undergo polymerization, forming the colloid caoutchouc.

There are strong arguments for the view that the constitution of the parent substance present in the latex is nearly related to that of isoprene. This remarkable hydrocarbon of the formula $C_5 H_8$, first obtained by Greville Williams from the dry distillation of rubber, is an unsaturated olefinic hydrocarbon, which is found among the products resulting from heating caoutchouc. It readily polymerizes, forming di-pentene. Bouchardat noticed that this hydrocarbon obtained from the pyrogenic decomposition of caoutchouc furnished a substance identical with rubber when acted on by hydrochloric acid and under other conditions. To Wallach and also to Tilden is due the further important observation that when isoprene prepared from oil of turpentine is kept for some time, it gradually passes into a substance having all the characteristic properties of caoutchouc.

I have very briefly drawn attention to the present position of our knowledge of the chemistry of caoutchouc in illustration of the interest which attaches to the examination of vegetable products, and also because of the immense importance of the problem from the practical and commercial standpoint. Chemistry in this case holds the premier position in reference to this subject, and, to a large extent, may be said to hold the key to the future of the rubber industry in all its phases. The

discovery of better methods of coagulation, preparation, and purification will be effected through chemical investigation, as will also the determination of the manner of utilizing the various other plants which furnish rubber-like latices. That the physical properties of raw rubber, on which its technical value depends, are to be correlated with the chemical composition of the material there can be no doubt. The chemical analysis of raw rubber, as at present conducted, is, however, not always to be taken by itself as a trustworthy criterion of quality, and more refined processes of analysis are now needed. Although the finest caoutchouc for technical purposes is only yielded by some half-dozen plants, under the names of which these varieties of caoutchouc pass, there can scarcely be a doubt that the elastic substance in each case possesses a very similar, if not identical, chemical structure. Nearly all the latices and similar fluids furnished by plants contain more or less caoutchouc. Even opium, which is the dried juice of the capsule of the poppy, contains caoutchouc, whilst the opium yielded by certain Indian species contains a notable proportion. Chemistry must determine the means by which caoutchouc can best be separated from these relatively poor latices. In view of the increasing production of the nearly pure caoutchouc, which is furnished by *Hevea brasiliensis*, *Funtumia elastica*, *Castilloa elastica*, *Ficus elastica*, and a few other plants which occur or can be cultivated in several of our tropical possessions, the question is not a pressing one at the moment.

Moreover, it cannot be doubted that chemical science will, sooner or later, be able to take a definite step towards the production of rubber by artificial means.

The production of caoutchouc by chemical means has, indeed, virtually been accomplished in its formation from isoprene. The exact nature of this change has still to be determined. When this has been done it will only remain to cheapen the cost of production to make the manufacture of synthetic rubber a purely practical problem. I should be the last to discourage the great extension of rubber planting which is now taking place. It is warranted by the present demand for the material. It has also to be remembered that the actual cost of producing raw rubber, which is at present about 1*s*. per ℔., will probably be reduced, and the market price of rubber may eventually be so considerably lowered that, as with quinine, the synthetic production could not be profitably carried on. That is a question which involves many factors at present unknown, and only time can decide. Chemists may, however, confidently predict that before the British Association again meets at York the synthetic production of rubber will be a fully accomplished fact.

As I have said, our science is concerned with nearly every problem connected with the great rubber industry, and in concluding these few remarks I may allude to the production of vulcanized rubber depending on the formation of additive compounds of the hydrocarbon with sulphur. In this connexion I should mention the recent experiments of Mr. Bamber in Ceylon, which appear to show that vulcanization may be accomplished by acting on the uncoagulated latex with chloride

of sulphur. If this proves to be practicable, it may mean the transference to the tropics of the subsidiary industry of vulcanization, which is at present carried on in Europe.

Owing to the importance and interest which attach to the chemistry of rubber, it is to form an important feature in the work of this section at the York meeting. Papers will be contributed by some of the best known workers in this field, by Professor Tilden, and by Professor Harries, of Kiel, who will give an account of his recent work; whilst Mr. Pickles, of the Imperial Institute, will present a report summarizing the whole of our chemical knowledge of the subject.

The chemical investigation of raw materials often raises, unexpectedly, problems of great scientific interest. The examination at the Imperial Institute of the seeds of the Para rubber tree (*Hevea brasiliensis*) has shown that they contain what proves to be a valuable drying oil, and in the course of the investigation it was ascertained that there is also present in the seeds an enzyme closely allied to, if not identical with, lipase, which is capable of splitting the oil by hydrolysis into glycerin and the free fatty acid. Subsequently, during the examination of other oil seeds, similar enzymes have been detected, and it would appear probable that most oil seeds may prove to contain an enzyme capable of decomposing the fatty constituents.

Another subject of great chemical interest and botanical importance which has come into prominence in connexion with the Indian and colonial work of the Imperial Institute is to be included in a joint discussion which has been arranged with the section of Botany. I refer to the production of prussic acid by plants, which, as I have elsewhere suggested, it is convenient to refer to as cyanogenesis. In this discussion we shall have the advantage of the co-operation of Professor van Romburgh and Dr. Greshoff, whose work with Dr. Treub, of Java, on this subject is known to chemists and botanists alike. The history of the origin of the several investigations in which Dr. Henry has been associated with me is not without interest in connexion with the principal subject of this address. During the first British expedition to the Soudan against the Mahdi a number of transport animals were poisoned through eating a small vetch which springs up in the Nile Valley during the fall of the river. The plant (*Lotus arabicus*) is well known to the Arabs, by whom it is cut when fully grown, and used as fodder for animals.

The results of the investigation of this matter, which were communicated to the Royal Society, proved that the young plant generated prussic acid when crushed with water. It was found to contain a new glucoside, lotusin, together with an enzyme capable of decomposing it into prussic acid, dextrose, and a yellow colouring matter, lotoflavin.

The glucoside is of special chemical interest, as being the only one known which contains the cyanogen group attached in the molecule to the sugar residue. Further investigation has shown that other fodder plants, which are occasionally poisonous, owe this character to the existence of other cyano-

genetic glucosides. In a series of papers communicated to the Royal Society, Dr. Henry and I have described the properties and constitution of dhurrin from *Sorghum vulgare*, and of phaseolunatin, which we have shown to be responsible for the production of prussic acid by *Phaseolus lunatus* (Lima beans), *Manihot utilissima* (cassava or tapioca), and by linseed (the flax plant). Phaseolunatin is remarkable in furnishing acetone as one of its products of hydrolysis. The investigation, besides fulfilling the primary purpose for which it was carried out, has raised a host of problems—as to the constitution of glucosides, the nature of the enzymes which accompany them in the plants, and also in relation to the fundamental question of plant metabolism.

Another subject of imperial as well as national importance is to be the subject of a joint discussion with the section of Physiology. I refer to the problem of diet. As chemists, we are interested in this subject chiefly from the point of view of the composition of foods, and of the molecular structure which is associated with dietetic value. The first attempt to deal with the matter from the scientific side was made by a great chemist, Liebig. We are now in a position to investigate the problem more minutely, and the work of American physiologists has already led to important results. We have still to learn how materials, such as rice and potatos, which are nearly free from proteids, continue nevertheless to serve as the main diet of large numbers of people. It would seem that the best plan of operations will be for physiologists to settle, by the accurate methods now available, the precise value of typical food stuffs, and for the chemist to deal with these in relation to their composition, and finally with reference to the constitution of their constituents. The time has come when an advance must be made from the chemical side in the analytical methods employed for gauging the value of food materials.

I feel that I have said much, but that I have left still more unsaid on many topics. I must leave almost untouched the entire subject of mineral chemistry, which is not only important in connexion with the determination of the resources of India and the colonies, but is also a subject somewhat neglected on its chemical side, which has been recently brought into prominence through the discovery of radio-activity.

The new radio-active mineral thorianite, from Ceylon, of which Mr. Blake and I have given an account to the Royal Society, brings me at once to a subject which raises the most fundamental of chemical questions, the nature of the elements and of the atom. The recent discussions of this subject have become so purely speculative that, whilst chemistry is bound to follow the lead of physics in this matter, chemists are inclined to consider that more well-ascertained facts are needed for any further discussion to be profitable from the chemical side.

In this address I have ventured to urge the fuller recognition by Government of the scientific method as a powerful instrument in promoting the commercial development of the colonies, and I have drawn attention to the important part

the science of chemistry can play in the imperial work of developing the resources of our possessions.

No apology is needed in this place for directing attention to a subject which involves a most important practical application of our science, since one of the principal functions of the British Association is to bring science into close touch with the problems of our national life, and to interest the general public in the application of science to their solution.

I have, however, also shown that many problems of the highest scientific interest arise in connexion with the investigation of these economic problems.

FORESTRY IN THE WEST INDIES.

In Dr. Schlich's *Manual of Forestry*,* Vol. I, the third part is devoted to a discussion of the 'Forest Policy in the British Empire.' The following account is given of the state of affairs as regards forestry in the West Indies :—

These numerous islands have an area of 12,010 square miles and a population of 1,583,480, making an average of 132 to the square mile. The density of population differs very greatly in the several islands.

There is a certain similarity, from a forest point of view, in all these islands, inasmuch as most of them require the preservation of the forests for the production and regulation of the water supply and to prevent erosion and denudation. Their forests contain a large number of species of timber trees. Of these, mahogany, cedar, and logwood, are the most important from a commercial point of view. They also contain other dye-woods, and they yield gums and resins as well as rubber.

It will be impossible to deal with all the islands; some remarks regarding a few will serve to show how forest conservancy stands, and what is needed. Trade returns are available for a few only, as far as forest produce is concerned.

JAMAICA.

The island of Jamaica lies between the 17th. and 19th. degrees of latitude: its greatest length is about 150 miles, while its breadth varies between 20 and 50 miles. The island has an area of 4,207 square miles and a population of 766,516, which makes 182 to the square mile. Of the total area, about 1,250 square miles are said to be still forest or jungle, which is equal to 30 per cent. of the total area. This shows that there is rather more than 1 acre of forest and jungle for every inhabitant.

* *Manual of Forestry:* by W. Schlich, Ph.D., C.I.E., F.R.S., F.L.S., M.A. *London: Bradbury, Agnew & Co., Ltd., 10, Bouverie Street, 1906.*

Formerly, the island had far more forest. The history of the destruction of forest is the history of the cultivation by the negros. They have now for a long period of time carried on shifting cultivation for the production of yams. Another agency in the process of destruction is the cultivation of ginger. It is estimated that some 30,000 acres of forest land are cleared annually, cultivated for a year or two and abandoned. In other words, about 4 per cent. of the forest area is cleared annually, and the whole is gone over in about twenty-five years, excepting certain areas which are inconveniently situated. The result is almost complete denudation of the southern slopes of the Blue Mountains, between 2,000 to 4,000 feet elevation.

The forests contain chiefly hardwoods, with a small number of soft woods. Of species and genera we find cedar (*Cedrela odorata*), *Juniperus bermudiana*, *Podocarpus*, *Calophyllum*, *Terminalia*, mahogany (*Swietenia Mahagoni*), *Mangifera*, logwood (*Haematoxylon campechianum*), *Paritium* (two species yielding fibre from the bark), *Bambusa vulgaris*, *Eugenia*, cocoa-nut, lignum vitae (*Guaiacum officinale*), fustic (*Maclura tinctoria*), and many others. The most important trees are:—

(1) Cedar, very valuable; at present chiefly mature trees are found, showing that the treatment of the forests has prevented reproduction.

(2) Mahogany of very superior quality is said to have been extracted in former times. What remains now is of inferior quality. It is, however, doubtful whether the quality was really much better in former times. The quantity now exported is very small.

(3) Logwood was introduced in 1715; it took root in the island and spread rapidly on the lower lands. The exports of this important dye-wood have, however, fallen off lately. They were:—

During the period	1888-93	100,989 tons a year
,, ,, ,,	1900-4	36,828 ,, ,, ,,

In value the exports fell from £350,003 to £97,688.

(4) Fustic, another dye-wood, showed an increase:—

Exports during the period	1888-1893	2,269 tons a year
,, ,, ,, ,,	1900-4	4,514 ,, ,, ,,

On the other hand, there is a considerable import of lumber and shooks, so that the balance between exports and imports of timber generally stands as follows:—

Average annual exports during the period 1900-4:—

Logwood	£97,688
Fustic	11,387
Spars	5,150
Total exports ...	£114,225

Average annual imports during the same period:—

Lumber	£35,273
Shooks	32,067
Total ...	£67,340

Balance of exports over imports ...	£46,885
Add increase in the export of logwood extract, about	10,000
Grand total	£56,885

There can be no doubt that the exports have, during the years 1888 to 1904, fallen off by not less than £200,000 a year.

The Crown lands of Jamaica are stated to comprise an area of 75,000 acres, but further lands have probably reverted to Government since the last return. The 75,000 acres are situated chiefly on the Blue Mountains, in St. Ann and Trelawny; they include the head waters of the Rio Grande. The Crown lands are under the Director of Public Works;* there is no separate Forest Department.

The authorities of Jamaica were of opinion, some years ago, that forest conservancy was not necessary, as lumber could be imported from America at cheap rates. Since then the exports of logwood have very considerably fallen off, and it appears that deforestation has commenced to interfere with the water supply in the eastern districts; moreover, forests are necessary to prevent, or at any rate reduce, a torrential flow of the rivers and to protect the lowlands. Under any circumstances, the forests on the main ridge should be preserved. Hence, the following measures seem indicated:—

(1) Reservation of the highlands on the Blue Mountains and elsewhere.

(2) Demarcation and survey of the reserves; their protection against fire, theft, alienation, and trespass.

Barbados.

This island has an area of 166 square miles and a population of 195,588, which makes 1,178 to the square mile. The island has a line of hills running from north to south rising to 1,145 feet above the sea; this hill range is intersected by ravines.

Owing to the great density of population about 100,000 acres, out of a total of 106,000, are used for the cultivation of sugar-cane and other crops; hence only a small portion of the island can be classed as forest. What remains of the

* Since 1890 there has been a separate Crown Lands Department, of which the Surveyor General is head.—[Ed. *W.I.B.*]

woods contains mahogany, cedar, lignum vitae, and other trees. Practically all timber for use is now imported. During the five years 1900 to 1904 the mean annual imports were valued at:—

Lumber	... ...	£25,930
Staves and shooks	... ...	£27,986
Total	...	£53,916

There is little room for forest conservancy, since nearly the whole of the land is required for cultivation.

Trinidad.

The island has an area of 1,754 square miles and a population of 255,148, equal to 145 to the square mile.

It is stated that of the total area about two-thirds are cultivable, while the other third consists chiefly of swampy ground, rocky and useless land. About 454,000 acres are in the hands of private proprietors. Of the Crown lands, 346,000 acres are classed as cultivable, 223,000 acres are poor land, and the rest swamps and waste.

There are three ranges of hills in the island. The chief objects of reserving the forest lands are: (1) to protect the sources of the water supply, and (2) the protection of valuable timber. The reserves, or proposed reserves, are mostly situated in the three hill ranges, but some of the areas are on low and cultivable land, as they are required to supply fuel to towns and villages. They may be classified as follows:—

	Square miles.
Reserves for the protection of the water supply	252
Reserves for the supply of fuel	30
Reserves forming a wind-break on the east coast ...	11
Total ...	293

This area is equal to 17 per cent. of the total area. Most of the accessible areas are now poor in mature timber. The forests contain logwood, cedar, fustic, bullet wood (*Mimusops globosa*), mahogany, and numerous other species.

An Indian forest officer has now charge of the forests.

The imports of timber during the five years 1900-4 amounted, on an average, to a value of £59,000 a year.

Tobago.

The island is situated close to Trinidad; it has an area of 114 square miles and a population of 18,751, or 165 to the square mile. The Crown lands occupy about 20 square miles, or 18 per cent. of the total area. The forest question should be dealt with in the same way as in the case of Trinidad. The forest officer mentioned above deals with both Trinidad and Tobago.

St. Lucia.

The island has an area of 233 square miles and a population of 49,883, or 214 to the square mile. The forests are estimated to cover about 80 square miles, or about one-third of the total area. They are situated in the centre of the island. Their composition is similar to that of the adjoining colonies. The chief feature is, however, the general appearance of balata (*Mimusops*), and other *Sapotaceae* and *Laurineae*, which yield valuable timber. The local demand is as yet small. The streams are mostly of a torrential character; hence denudation is active. It follows that the forests in the hills should be preserved. The lands in question are mostly Crown lands. The forests yield, besides timber, numerous articles of other forest produce, such as fibres, gums, and gum resins.

British Honduras.

This colony has an area of 7,562 square miles and a population of 37,479, or about five to the square mile. Of the total area only about 90 square miles are under cultivation, all the rest being forest and jungle. These contain mahogany and logwood.

The average annual exports, as far as the data are available, show the following items:—

	Tons.	Value.
Timber, chiefly mahogany	16,000	£140,000
Logwood	16,000	£123,000
Total	32,000	£263,000

These exports represent some 90 to 95 per cent. of the total exports of the colony; hence it is of paramount importance to secure a continuance of this valuable item of export.

Rubber of the average annual value of £2,637 was also exported.

In 1885, Mr. E. Hooper, of the Indian Forest Service, was deputed to visit British Honduras to report on the forests. He states the following:—

'It is a prevailing belief in the colony that the supply of mahogany is not being reduced. No doubt, there is a large amount still standing, but it is so far from the seaboard that it is, under existing conditions of transport, practically valueless. Large trees are now generally found only far up the rivers, while the accessible forests yield chiefly small timber down to 10 inches square. All this indicates that the supply of good-sized mahogany will fall off, and it is questionable whether the export of it will continue to be an important factor in the progress of the colony. Certain rules have been passed to prevent the cutting of undersized trees (15 inches and under), but it appeared that great laxity prevailed in checking the cutting of undersized mahogany.'

So far Mr. Hooper. Unfortunately no information is available to show, whether, or to what extent, matters have

improved since Mr. Hooper's visit. It may, however, be said that, if ever a case were made out for the preservation and careful management of the forests of any colony, it is for those of British Honduras. To allow matters to go on, as at the time of Mr. Hooper's visit, would mean the destruction of the bulk of the exports of the colony. In the author's opinion, a competent forest officer should be appointed without delay, to organize a small Forest Department and to introduce the measures which are necessary to perpetuate the supply of mahogany and other valuable timbers.

British Guiana.

The colony has an area of 109,000 square miles, and a population of 293,958, or three to the square mile. By far the greater part of the country is covered with forest containing mostly hardwoods. There is no Forest Department.

During the years 1900 to 1904, the average annual exports of timber were valued at £22,574. On the other hand, the average imports of lumber were valued at £30,034. The average export of rubber during the five years 1900 to 1904 amounted to 524,496 ℔., valued at £36,416.

Considering the large stock of valuable hardwoods in the extensive forests of the colony, it seems worth while to consider the advisability of stimulating the export and perhaps establishing a forestry branch of the administration. This seems all the more desirable, as the average annual exports of balata gum have of late years rapidly risen. Without speedy protection, the export of rubber is likely to decrease again as rapidly as it has increased.

MANURIAL EXPERIMENTS WITH COTTON IN THE LEEWARD ISLANDS.

BY THE HON. FRANCIS WATTS, C.M.G., D.Sc., AND
H. A. TEMPANY, B.Sc., F.I.C., F.C.S.

The results of the second year's work on manurial experiments with cotton in the Leeward Islands are now reported on.*

The plan upon which these experiments were carried out was similar to that on which the same series of experiments was performed last year, and which was originally published in the *Agricultural News*, Vol. III, p. 237. It was as follows:—

The Imperial Department of Agriculture will provide the artificial manures for the experiments, and will supervise their application.

The planter co-operating will be required to prepare the land for the experiments and to plant the necessary dividing lines of pigeon peas; to weed and care for the crop during growth, taking all reasonable precautions for the prevention of insect and other pests, including the provision and application of proper insecticides; to gather the cotton from each plot separately, which can be readily done by having as many bags for storing cotton as there are plots in the series of experiments.

The necessary information concerning the weight of seed-cotton, of lint obtained per plot, and of the general nature and growth of the crop will be forwarded to the Government Laboratory for the purpose of preparing the proper report on the experiments, in a manner similar to that followed in the case of the experiments with sugar-canes. It is desirable that care be taken to provide for concise publication of results; fragmentary and piece-meal publication is to be deprecated.

In the season under review thirty-eight manurial experiments described below have been repeated as follows:—

In Antigua two series of experiments.

In St. Kitt's three series of experiments.

In Nevis two series of experiments.

In Montserrat one series of experiments.

Each experiment, with the exception of Nos. 31-38, was therefore repeated eight times.

The experiments consisted of the following:

(1) No manure.

(2) Pen manure.

*The results of last year's experiments were published in the *West Indian Bulletin*, Vol. VI, pp. 247-57.

Nitrogen Series.

(3) No nitrogen, 30 ℔. potash, 40 ℔. phosphate.

(4) 20 ℔. nitrogen as sulphate of ammonia, 30 ℔. potash, 40 ℔. phosphate.

(5) 30 ℔. nitrogen as sulphate of ammonia, 30 ℔. potash, 40 ℔. phosphate.

(6) 20 ℔. nitrogen as nitrate of soda, 30 ℔. potash, 40 ℔. phosphate.

(7) 30 ℔. nitrogen as nitrate of soda, 30 ℔. potash, 40 ℔. phosphate.

(8) 30 ℔. nitrogen as sulphate of ammonia, 30 ℔. potash. no phosphate.

(9) 20 ℔. nitrogen as sulphate of ammonia, no potash, no phosphate.

(10) 30 ℔. nitrogen as sulphate of ammonia, no potash, no phosphate.

(11) 20 ℔. nitrogen as nitrate of soda, no potash, no phosphate.

(12) 30 ℔. nitrogen as nitrate of soda, no potash, no phosphate.

Phosphate Series.

(13) No phosphate, 30 ℔. nitrogen, 30 ℔. potash.

(14) 40 ℔. phosphoric acid as basic phosphate, 30 ℔. nitrogen, 30 ℔. potash.

(15) 60 ℔. phosphoric acid as basic phosphate. 30 ℔. nitrogen, 30 ℔. potash.

(16) 80 ℔. phosphoric acid as basic phosphate, 30 ℔. nitrogen, 30 ℔. potash.

(17) 40 ℔. phosphoric acid as basic phosphate, no nitrogen, no potash.

(18) 40 ℔. phosphoric acid as superphosphate, 30 ℔. nitrogen, 30 ℔. potash.

(19) 60 ℔. phosphoric acid as superphosphate, 30 ℔. nitrogen, 30 ℔. potash.

Potash Series.

(20) No potash, 30 ℔. nitrogen, 40 ℔. phosphate.

(21) 20 ℔. potash as sulphate, 30 ℔. nitrogen, 40 ℔. phosphate.

(22) 30 ℔. potash as sulphate, 30 ℔. nitrogen, 40 ℔. phosphate.

(23) 40 ℔. potash as sulphate, 30 ℔. nitrogen. 40 ℔. phosphate.

(24) 40 ℔. potash as sulphate, no nitrogen, no phosphate.

Cotton Seed Meal Series.

(25) 3,000 lb. cotton seed.

(26) 600 lb. cotton seed.

(27) 300 lb. cotton seed, 30 lb. potash, no phosphate.

(28) 300 lb. cotton seed, no potash, 40 lb. phosphate.

(29) 300 lb. cotton seed, 30 lb. potash, 40 lb. phosphate.

(30) 300 lb. cotton seed, 30 lb. potash, 40 lb. phosphate, 30 lb. nitrogen.

Salt Series.

(31) 100 lb. salt alone.

(32) 200 lb. salt alone.

(33) 100 lb. salt, 30 lb. nitrogen, 30 lb. potash, 40 lb. phosphate.

(34) 200 lb. salt, 30 lb. nitrogen, 30 lb. potash, 40 lb. phosphate.

(35) 100 lb. salt, 300 lb. cotton seed.

Sulphate of Copper Series.

(36) 20 lb. sulphate of copper.

(37) 20 lb. sulphate of copper, 30 lb. nitrogen, 30 lb. potash, 40 lb. phosphate.

(38) 20 lb. sulphate of copper, 300 lb. cotton seed.

Note.—Plots Nos. 5, 14, and 22, also Nos. 8 and 13 are identical, so that one plot, that is, No. 5, will serve for 5, 14, and 22, and one plot, that is, No. 8, will serve for 8 and 13.

This year the salt and sulphate of copper series of experiments were performed only on the St. Kitt's station at La Guerite, it having been found, as the result of last year's work, that the influence exerted by these substances was, on the whole, deleterious.

Owing to drought and other detrimental circumstances some of the experiments laid out were not carried to a successful conclusion.

The detailed results obtained on the various experimental plots are given in Table I, the means for all stations in Table II, and the means for the two years' working in Table III.

Considering first the results on the various experiment stations, the value of the information to be gained from the different plots varies. Perhaps the greatest weight may be attached to series i and ii at La Guerite, St. Kitt's.

Of the Antigua series (a) was grown from St. Vincent seed, and (b) from Gilbert's seed; the plots were grown side by side. Of these two returns more importance may probably be attached to the (a) series, grown from St. Vincent seed; the (b) series, grown from Gilbert's seed having suffered from the attacks of the leaf-blister mite (*Eriophyes gossypii*).

In St. Kitt's the three series at La Guerite were planted at different times: series i was planted in June, series ii in

August, and series iii in October. The effect of late planting on the yield is most marked.

In compiling the table of averages, series iii has not been taken into account, as, owing to the late planting, the results were unreliable.

In the experiments at Dagenham, Montserrat, owing to various circumstances, gaps occurred in some of the plots. On this account two returns are given for the one experiment: in the first the actual returns from each of the plots are given, and in the other the yield has been calculated to allow for the missing plants where they occurred.

The results of any individual plot are irregular, but when we consider the average or mean of all the plots, these irregularities tend to disappear, this being especially the case with the means for two years' experiments.

Turning now to the average results:—

If, as was done last year, we consider differences on the no-manure plots of less than 60 lb. of seed-cotton (equal to about 16 lb. of lint) per acre as being too small to be taken serious account of, we find that, as the results of the past season's work, thirteen plots out of twenty-eight have given differences exceeding this amount. This is very considerably in excess of what was observed last year, but it is important to note that the majority of these differences are minus quantities. If we sum all the plus differences and all the minus differences on the no-manure plot, we find that we have an aggregate plus difference of 258·0 lb. of seed-cotton, and an aggregate minus difference of 1,467·2 lb. of seed-cotton. Thus the result of the past season's experiments has been that applications of manure have, on the average, occasioned an actual decrease in the yield of seed-cotton.

The means for two years show considerably more regularity. The results represent the average of nineteen repetitions of each experiment under varying conditions of soil and rainfall, and may be regarded with some confidence. In the difference column we see that only six experiments have given differences from no manure of more than 60 lb. of seed-cotton per acre. It is perhaps a somewhat significant fact, that on the means for two years the aggregate minus difference on no manure is in excess of the aggregate of the plus differences, the aggregate minus difference being 774·8 lb. of seed-cotton, and the aggregate plus difference being 385·6 lb. of seed-cotton.

On the whole, the results now under review amply confirm the conclusion arrived at as the outcome of last year's work, namely, that the yield of seed-cotton is more influenced by season and good soil conditions and tilth, than by artificial manures.

The thanks of the Department are due to those who have assisted in the carrying out of these experiments, and the hope is expressed that they will continue to co-operate with the Imperial Department of Agriculture in carrying out similar experiments on the coming crop.

TABLE I. Cotton Manurial Experiments, Leeward Islands. Yield of Seed-cotton in Pounds.

Experiment No.	Antigua.		St. Kitt's.			Nevis.		Montserrat.		Average.		Difference on no manure.
	Skerrett's A.	Skerrett's B.	La Guerite I.	La Guerite II.	La Guerite III.	Cane Garden.	Round Hill.	Dagenham (as reaped).	Dagenham (corrected for missing plants).	Pounds per plot.	Pounds per acre.	
1	27·75	10·25	45·13	26·25	3·00	12·20	24·00	15·50	15·50	23·01	920·4	...
2	15·37	9·50	38·00	27·20	4·50	16·00	23·00	20·04	20·19	21·32	852·8	− 67·6
3	25·50	10·75	21·38	31·06	4·90	12·00	25·00	19·31	19·31	20·71	828·4	− 92·0
4	29·37	10·00	39·20	28·12	5·60	10·00	24·00	17·78	17·78	22·64	905·6	− 14·8
5	39·50	16·44	25·70	36·40	6·20	13·50	27·00	16·78	16·78	25·04	1,001·6	+ 81·2
6	28·62	12·00	33·50	35·75	5·12	13·00	20·00	16·87	17·03	22·84	913·6	− 6·8
7	33·50	13·25	24·13	32·06	5·25	17·00	22·00	18·87	19·19	23·02	920·8	+ 0·8
8	29·37	15·75	32·90	31·56	6·55	14·00	25·00	18·94	19·19	23·97	958·8	+ 38·4
9	29·75	10·50	20·25	29·90	5·70	10·00	18·00	19·03	19·19	19·65	786·0	− 134·4
10	35·87	15·75	28·38	30·56	6·00	11·00	20·00	20·43	20·72	23·18	927·2	+ 6·8
11	26·12	13·25	40·90	33·62	6·20	14·00	21·00	20·03	20·19	24·15	966·0	+ 35·6
12	25·93	6·50	41·75	28·30	4·25	9·50	23·00	19·25	19·25	22·03	881·2	− 39·2
13	29·37	15·75	32·90	31·56	6·55	14·00	25·00	18·94	19·19	23·97	948·8	+ 28·4
14	39·50	16·44	25·70	36·40	6·20	13·50	27·00	16·75	16·78	25·04	1,001·6	+ 81·2
15	29·50	16·50	43·70	24·43	5·80	12·00	19·00	19·62	19·62	23·53	941·2	+ 20·8
16	26·12	8·00	38·00	32·25	3·50	16·00	21·00	18·87	18·87	23·32	932·8	+ 12·4
17	19·75	11·81	29·13	30·70	1·90	14·00	25·00	18·03	18·03	21·20	848·0	− 72·4
18	28·62	11·25	29·30	27·56	3·50	13·00	20·00	19·12	19·12	21·26	850·4	− 70·0
19	26·00	11·25	34·80	28·12	3·80	13·00	21·00	17·25	17·53	21·67	866·8	− 53·6

TABLE I.—COTTON MANURIAL EXPERIMENTS, LEEWARD ISLANDS. YIELD OF SEED-COTTON IN POUNDS.—(*Concluded.*)

Experiment No.	Antigua.		St. Kitt's.			Nevis.		Montserrat.		Average.		Difference on no manure.
	Skerrett's A.	Skerrett's B.	La Guerite I.	La Guerite II.	La Guerite III.	Cane Garden.	Round Hill.	Dagenham (as reaped).	Dagenham (corrected for missing plants).	Pounds per plot.	Pounds per acre.	
20	27·12	13·00	23·70	28·20	4·60	15·00	26·00	19·62	19·77	21·81	872·4	– 48·0
21	30·12	10·38	18·70	21·75	5·75	16·50	24·00	21·31	21·47	20·39	815·6	– 104·8
22	39·50	16·44	25·70	36·40	6·20	13·50	27·00	16·78	16·78	25·04	1,001·6	+ 81·2
23	20·62	7·87	29·80	34·80	5·60	15·00	22·00	19·88	21·53	20·33	813·2	– 107·2
24	15·87	9·00	24·75	26·43	4·90	16·00	24·00	16·06	16·81	18·98	759·2	– 161·2
25	26·87	11·00	36·90	26·00	5·40	18·00	23·00	15·70	16·00	21·97	878·8	– 41·6
26	21·50	7·00	44·90	27·60	2·75	20·00	19·00	17·28	18·59	22·65	906·0	14·4
27	22·87	8·75	38·70	35·60	2·60	15·00	18·00	15·00	17·00	22·13	885·2	35·2
28	19·25	12·31	32·90	35·60	3·00	14·00	19·00	14·06	15·00	21·15	846·0	– 74·4
29	26·50	4·50	25·50	23·43	4·80	13·00	15·00	12·72	14·56	17·51	700·4	– 220·0
30	19·50	9·00	30·60	30·90	1·60	14·00	21·00	15·31	16·87	20·27	810·8	– 109·6
31	...	...	18·90	36·50	2·00	...	...	...	...	...	...	...
32	...	...	23·90	23·00	0·25	...	...	...	...	...	...	...
33	...	...	27·06	32·60	1·30	...	...	...	...	...	...	...
34	...	...	27·06	23·12	2·00	...	...	...	...	...	...	...
35	...	...	27·40	20·90	3·00	...	...	...	...	...	...	...
36	...	...	33·00	20·60	1·60	...	...	...	...	...	...	...
37	...	...	22·90	18·25	2·20	...	...	...	...	...	...	...
38	...	...	31·30	25·90	2·50	...	...	...	...	...	...	...

TABLE II.

Yield of Seed-cotton in Pounds.

Mean of Seven Plots.

Experiment No.	Pounds per plot.	Pounds per acre.	Difference on no manure per acre.
1	23·01	920·4	...
2	21·32	852·8	– 67·6
3	20·71	828·4	– 92·0
4	22·64	905·6	– 14·8
5	25·04	1,001·6	+ 81·2
6	22·84	913·6	– 6·8
7	23·02	920·8	+ 0·8
8	23·97	958·8	+ 38·4
9	19·65	786·0	– 134·4
10	23·18	927·2	+ 6·8
11	24·15	966·0	+ 35·6
12	22·03	881·2	– 39·2
13	23·97	948·8	+ 28·4
14	25·04	1,001·6	+ 81·2
15	23·53	941·2	+ 20·8
16	23·32	932·8	+ 12·4
17	21·20	848·0	– 72·4
18	21·26	850·4	– 70·0
19	21·67	866·8	– 53·6
20	21·81	872·4	– 48·0
21	20·39	815·6	– 104·8
22	25·04	1,001·6	+ 81·2
23	20·33	813·2	– 107·2
24	18·98	859·2	– 161·2
25	21·97	878·8	– 41·6
26	22·65	906·0	– 14·4
27	22·13	885·2	– 35·2
28	21·15	846·0	– 74·4
29	17·51	700·4	– 220·0
30	20·27	810·8	– 109·6

TABLE III.

Yield of Seed-cotton in Pounds.

Mean of Two Years' Experiments (19 Plots).

Experiment No.	Pounds per plot.	Pounds per acre.	Difference on no manure per acre.
1	21·30	852·0	...
2	21·14	845·6	− 6·4
3	20·94	837·6	− 14·4
4	21·57	862·8	+ 10·8
5	22·25	890·0	+ 38·0
6	21·82	872·8	+ 20·8
7	20·83	833·2	− 18·8
8	20·93	837·2	− 14·8
9	20·19	807·6	− 44·4
10	22·40	896·0	+ 44·0
11	22·82	912·8	+ 60·8
12	21·51	860·4	+ 8·4
13	20·57	822·8	− 29·2
14	21·41	856·4	+ 4·4
15	22·34	893·6	+ 41·6
16	22·65	906·0	+ 54·0
17	20·03	801·2	− 50·8
18	19·88	795·2	− 56·8
19	20·14	805·6	− 46·4
20	20·91	836·4	− 15·6
21	18·70	748·0	− 104·0
22	21·67	866·8	+ 14·8
23	18·64	745·6	− 106·4
24	19·61	784·4	− 67·6
25	20·83	833·2	− 18·8
26	20·44	817·6	− 34·4
27	20·75	830·0	− 22·0
28	23·50	940·0	+ 88·0
29	19·23	769·2	− 82·8
30	20·27	810·8	− 41·2

MANURIAL EXPERIMENTS WITH COTTON IN BARBADOS.

BY J. P. D'ALBUQUERQUE, M.A., F.I.C., F.C.S.,

and J. R. BOVELL, F.L.S., F.C.S.

Owing to the rapid increase in the cotton industry in Barbados, it was deemed desirable to institute a series of manurial experiments to ascertain the requirements of the Sea Island cotton plant under the soil and climatic conditions which exist in the cotton-growing districts of Barbados.

The experiments were started during the cotton season of 1905. The objects of the experiments were to ascertain (*a*) the quantity of nitrogen needed to produce the best results when combined with sufficient phosphoric acid and potash to enable that constituent to exercise its full effects; (*b*) to ascertain in like manner the requirements of the cotton plant as regards phosphoric acid when combined with sufficient nitrogen and potash: and (*c*) its requirements as regards potash when combined with sufficient nitrogen and phosphoric acid.

One series of experiments was started, with the permission of Mr. E. W. Mahon, the attorney of the estate, and the co-operation of Mr. E. H. S. Rose, the manager, at Bentley plantation, Christ Church, and another, with the permission of Mr. H. E. Pilgrim, the attorney of the estate, and the co-operation of Mr. L. S. Drayton, the manager, at Carlton, St. James.

The following is a list of the experiments carried out at each estate, viz:—

I. No Manure.

II. Nitrogen Series.

	Nitrogen as sulphate of ammonia	0 lb.
1.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	10 ,,
2.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	20 ,,
3.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	30 ,,
4.	Phosphoric acid as superphosphate of lime ..	60 ,,
	Potash as sulphate of potash	20 ,,

III. Phosphate Series:—

	Nitrogen as sulphate of ammonia	20 ,,
1.	Phosphoric acid as superphosphate of lime ...	0 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	20 ,,
2.	Phosphoric acid as superphosphate of lime ...	20 ,,
	Potash as sulphate of potash	20 ,,

	Nitrogen as sulphate of ammonia	20 lb.
3.	Phosphoric acid as superphosphate of lime ...	40 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	20 ,,
4.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	20 ,,
5.	Phosphoric acid as superphosphate of lime ...	80 ,,
	Potash as sulphate of potash	20 ,,

IV. Potash Series.

	Nitrogen as sulphate of ammonia	20 ,,
1.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	0 ,,
	Nitrogen as sulphate of ammonia	20 ,,
2.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	10 ,,
	Nitrogen as sulphate of ammonia	20 ,,
3.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	20 ,,
	Nitrogen as sulphate of ammonia	20 ,,
4.	Phosphoric acid as superphosphate of lime ...	60 ,,
	Potash as sulphate of potash	30 ,,

The plots in the nitrogen series, No. 3, the phosphate series, No. 4, and the potash series, No. 3, are identical.

The detailed results are given in Tables I-VI.

RAINFALL AT THE COTTON MANURIAL EXPERIMENT STATIONS FROM JANUARY 1, 1905, TO MAY 31, 1906.

Months.	Bentley.		Carlton.	
	Days.	Inches.	Days.	Inches.
1905				
January	29	2·33	9	2·52
February ...	16	1·64	10	1·29
March	11	2·38	7	2·70
April	8	0·92	7	1·14
May	7	0·97	12	1·81
June	21	6·87	15	5·78
July	18	4·27	17	5·86
August	19	5·94	17	6·98
September ..	17	5·23	12	6·46
October	17	3·48	14	4·97
November ..	15	4·84	12	8·30
December ..	10	2·07	11	2·92
1906				
January	16	1·65	14	1·86
February ...	8	1·11	16	1·26
March	8	0·75	11	1·50
April	4	1·12	5	1·40
May	10	1·19	5	0·78
	225	46·76	194	57·53

ANALYSES OF THE SOIL OF THE COTTON MANURIAL EXPERIMENT STATIONS FOR 1905-6.

Mechanical Analyses.

Results calculated to soil dried at 100° C.

	Diameter of particles.	Bentley.*	Carlton.†
		Per cent.	Per cent.
Gravel	3 mm. to 1 mm.	4·9	5·7
Coarse sand ...	1 ,, ,, 0·5 ,,	2·5	4·3
Medium sand ...	0·5 ,, ,, 0·25 ,,	2·3	7·8
Fine sand ...	0·25 ,, ,, 0·05 ,,	16·0	31·8
Silt	0·05 ,, ,, 0·01 ,,	27·3	18·1
Fine silt ...	0·01 ,, ,, 0·002 ,,	21·2	14·9
Clay	0·002 ,, ...	25·8	17·9
		100·0	100·0
Fine soil ...	0·5 mm. to ...	92·6	90·0

* 'A loamy clay soil.' † 'A clayey loam soil.'

Chemical Analyses.

Results calculated to soil dried at 100° C.

Constituents.	Bentley. Per cent.	Bentley. Approx. pounds per acre.	Carlton. Per cent.	Carlton. Approx. pounds per acre.
Insoluble silicates and silica	53·756	1,612,680	63·918	1,917,540
Soluble silica	·570	17,100	·094	2,820
Potassium oxide	·155*	4,650	·149*	4,470
Sodium oxide	·181	5,430	·286	8,580
Calcium oxide	3·400	102,000	2·020	60,000
Magnesium oxide	·424	12,720	·480	14,400
Manganese oxide	·820	24,600	·220	6,600
Iron and aluminium oxides	27·310	819,300	24·254	727,620
Phosphoric anhydride ...	·170†	5,100	·086	2,580
Sulphuric anhydride ...	·079	2,370	·087	2,610
Carbonic anhydride ...	1·065	31,950	1·015	30,450
Combined water and organic matter ...	12·760‡	382,800	8·795‡	263,850
	100·690	3,020,700	101·404	3,042,120

* (1) Containing available potash ... ... ·011 per cent.
* (2) ,, ,, ,, ... ·033 ,, ,,
† Containing phosphoric anhydride, soluble in 1 per cent. citric acid ... ... ·031 ,, ,,
‡ (1) Containing nitrogen ... ... ·175 ,, ,,
‡ (2) ,, ,, ... ·147 ,, ,,

Composition of the Chemical Manures Employed.

	Nitrogen.	Phosphoric Acid. Soluble	Phosphoric Acid. Reverted	Phosphoric Acid. Insoluble	Potash.
Sulphate of ammonia	20·22				
Sulphate of ammonia	20·29				
Superphosphate of lime		16·04	3·05	·38	
Sulphate of potash					52·50

Assimilable phosphoric acid 19·09 per cent.

Certificate of Analysis of Farmyard Manure Applied to Lower Mill Field.

Carlton Plantation.

Moisture	46·30
Organic matter*	15·50
Insoluble siliceous matter...	21·00
Phosphoric anhydride†	·27
Potassium oxide	·22
Undetermined substances	16·71
	100·00

* Containing nitrogen ... ... ·32

† Equal to tricalcium phosphate ... ... ·59

Bentley Plantation.

North Negro Yard Field – Line 6 feet x 6 feet.

The plant canes were reaped during February 1905 : the field was planted in imphee, very little of which, however, grew. What did grow, as soon as it reached maturity, was fed off, along with the young ratoons, to the estate animals. The cane holes were dug in June, and the mould thrown on the old stools. In July the field was given two cuts with a subsoil plough in the bank in an easterly and westerly direction. The cane holes were pulverized in August, and the mould broken up by a plough, and that from the cane holes, after being pulverized, was hoed over and levelled. The spaces to the west of the cane holes were not tilled.

The cotton was planted on August 7, 1905. Chemical manure was applied on August 24 and 25. The first cotton of the first picking was picked on December 30, 1905, and the last on March 1, 1906. The second picking was commenced on May 1, 1906, and finished on May 25, 1906.

The cotton germinated regularly. The rainfall during the growth of the cotton was favourable, 27·38 inches falling from the beginning of August, the month in which the cotton was planted until the end of May. The plants were kept free from caterpillars and were well looked after.

Carlton Plantation.

Lower Mill Field—Line 5 feet x 5 feet.

After the canes were reaped in 1903 the field was planted in cassava, which was dug in July 1904. Sweet potatos were then planted in the following September, and reaped in February 1905. The field was then given two cuts with a plough in the bank in a northerly and southerly direction. The field, the rows of which were irregular, was then relined 5 feet x 5 feet, and cane holes were dug. Farmyard manure at the rate of 1 square per acre was applied in the cane holes on July 4 and 5, 1905, and covered.

Cotton was planted on July 18, 1905, but as the holes that had been made for it were so irregular, the plants were dug up and new holes dug, and cotton replanted on August 7. The chemical manure was applied on August 2 and 3, 1905. The first cotton was picked on December 23, 1905, and the last on February 7, 1906. Unfortunately, the 'Black Scale' (*Lecanium nigrum*) attacked the cotton plants at an early time, the consequence being that the yield was considerably reduced. In fact, to such an extent was the cotton attacked that, as will be seen from the tables, the results are unreliable, and have not, therefore, been taken into consideration.

Summary of the Results.

Nitrogen Series.

In this series there was a uniform increase from the addition of nitrogen, the best results being obtained where 30 ℔. of nitrogen as sulphate of ammonia were applied per acre, amounting to 279 ℔. of seed-cotton. The value of the manure was \$9·42, and the profit by manuring over no manure was \$10·11, and over no nitrogen \$9·36.

Phosphoric Acid Series.

In this series the best results were obtained where, in addition to 20 ℔. of nitrogen as sulphate of ammonia, and 20 ℔. of potash as sulphate of potash, 40 ℔. of phosphoric acid as superphosphate of lime were applied. In this case the increase due to manuring was 281 ℔. of seed-cotton. The value of the manure was \$6·64, and the profit by manuring over no manure was \$12·99, and over no phosphoric acid \$14·87.

Potash Series.

In this series the best results were obtained where, in addition to 20 ℔. of nitrogen as sulphate of ammonia, and 60 ℔. of phosphoric acid as superphosphate of lime, 20 ℔. of potash as sulphate of potash were applied. The increase here due to to the manure was 196 ℔. of seed-cotton. The value of the manure was \$7·77, and the profit by manuring over no manure \$5·55, and over no potash \$1·77.

In conclusion, we should like it to be clearly understood that, as the experiments have so far been conducted for only one season, it is undesirable to lay too much stress on them. We may, however, state that, as will be seen, the results are in accordance with those obtained with cotton experiments in other countries, and point to the necessity of a liberal supply of phosphoric acid being included in any manure applied to the cotton plant.

TABLE I.

Cotton Manurial Experiments at Bentley Plantation—North Negro Yard Field.

Size of Each Plot = 0·218 Acre. Nitrogen Series.

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no nitrogen.
1 & 18	Nitrogen (N) as sulphate of ammonia ... 0; Phosphoric acid (P_2O_5) as superphosphate 0; Potash (K_2O) as sulphate of potash ... 0	1,005 ... 763	236 ... 200	1,241 ... 963	$86·87 ... 67·41				
	Mean ...	884	218	1,102	$77·14				
2 & 17	Nitrogen (N) as sulphate of ammonia ... 0; Phosphoric acid (P_2O_5) as superphosphate 60; Potash (K_2O) as sulphate of potash ... 20	956 ... 853	296 ... 248	1,252 ... 1,101	$87·64 ... 77·07		$3·37 1·10		
	Mean ...	904½	272	1,176½	$82·35½	+ 74½	$4·47	+ $0·75	

TABLE I.—*Concluded.*

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no nitrogen.
3	Nitrogen (N) as sulphate of ammonia ... 10	1,047	278	1,325	$ 92·75		$1·65		
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...	...	...		3·37		
16	Potash (K_2O) as sulphate of potash ... 20	877	188	1,065	74·55		1·10		
	Mean ...	962	233	1,195	$ 83·65	+ 93	$6·12	- $0·39	$0·36
4	Nitrogen (N) as sulphate of ammonia ... 20	1,222	218	1,440	$100·80		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...	...	...		3·37		
15	Potash (K_2O) as sulphate of potash ... 20	980	176	1,156	80·92		1·10		
	Mean ...	1,101	197	1,298	$ 90·86	+ 196	$7·77	+ $5·95	+ $5·20
5	Nitrogen (N) as sulphate of ammonia ... 30	1,374	248	1,622	$113·54		$4·95		
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...	...	...		3·37		
14	Potash (K_2O) as sulphate of potash ... 20	1,008	133	1,141	79·87		1·10		
	Mean ...	1,191	190	1,381	$ 96·67	+ 279	$9·42	+ $10·11	+ $9·36

TABLE II.

COTTON MANURIAL EXPERIMENTS AT BENTLEY PLANTATION—NORTH NEGRO YARD FIELD.
PHOSPHATE SERIES.

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no phosphate.
1	Nitrogen (N) as sulphate of ammonia ... 0	1.005	236	1,241	$86·87				
&	Phosphoric acid (P_2O_5) as superphosphate 0	...	...	...	...				
18	Potash (K_2O) as sulphate of potash ... 0	763	200	963	67·41				
	Mean ...	884	218	1.102	$77·14				
6	Nitrogen (N) as sulphate of ammonia ... 20	969	212	1.181	$82·67		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate 0	...	...	...	...		...		
13	Potash (K_2O) as sulphate of potash ... 20	887	208	1,095	76·65		1·10		
	Mean ...	928	210	1,138	$79·66	+ 36	$4·40	– $1·88	

TABLE II.—*Continued.*

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no phosphate.
7 & 24	Nitrogen (N) as sulphate of ammonia ... 20 Phosphoric acid (P_2O_5) as superphosphate 20 Potash (K_2O) as sulphate of potash ... 20	1,066 ... 1,126	200 .. 290	1,266 . . 1,416	\$ 88·62 ... 99·12		\$3·30 1·12 1·10		
	Mean ...	1,096	245	1,341	\$ 93·87	+ 239	\$5·52	+ \$11·21	+ \$13·09
8 & 23	Nitrogen (N) as sulphate of ammonia ... 20 Phosphoric acid (P_2O_5) as superphosphate 40 Potash (K_2O) as sulphate of potash ... 20	1,028 ... 1,325	200 .. 212	1,228 .. 1,537	\$ 85·96 ... 107·59		\$3·30 2·24 1·10		
	Mean ...	1,176½	206	1,382½	\$ 96·77	+ 281½	\$6·64	+ \$12·99	+ \$14·87

TABLE II.—*Concluded.*

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no phosphate.
4	Nitrogen (N) as sulphate of ammonia ... 20	1,222	218	1,440	$100·80		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate 60	.	...	...	...		3·37		
15	Potash (K_2O) as sulphate of potash ... 20	980	176	1,156	80·92		1·10		
	Mean ...	1,101	197	1,298	$ 90·86	+ 196	$7·77	+ $5·95	+ $7·83
9	Nitrogen (N) as sulphate of ammonia ... 20	1,101	260	1,361	$ 95·27		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate 80	...	...	...	...		4·49		
22	Potash (K_2O) as sulphate of potash ... 20	1,112	194	1,306	91·42		1·10		
	Mean ...	1,106½	227	1,333½	$ 93·34	+ 231	$8·89	+ $7·31	+ $9·19

TABLE III.

Cotton Manurial Experiments at Bentley Plantation—North Negro Yard Field. Potash Series.

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no potash.
1 & 18	Nitrogen (N) as sulphate of ammonia ... 0; Phosphoric acid (P_2O_5) as superphosphate 0; Potash (K_2O) as sulphate of potash ... 0	1,005 ... 763	236 ... 200	1,241 ... 963	\$86·87 ... 67·41				
	Mean ..	884	218	1,102	\$77·14				
10 & 21	Nitrogen (N) as sulphate of ammonia ... 20; Phosphoric acid (P_2O_5) as superphosphate 60; Potash (K_2O) as sulphate of potash ... 0	1,132 ... 1,011	158 ... 212	1,290 ... 1,223	\$90·30 ... 85·61			\$3·30 ... 3·37	
	Mean ..	1,072	185	1,257	\$87·99	+ 155	\$6·67	+ \$4·18	

TABLE III—*Concluded.*

No. of Plot.	Manures used.	Seed-cotton in pounds per acre. First picking.	Seed-cotton in pounds per acre. Second picking.	Seed-cotton in pounds per acre. Total picking.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss of manuring per acre.	Profit or loss per acre on no potash.
11	Nitrogen (N) as sulphate of ammonia . 20	998	259	1,257	\$ 87·99			\$3·30	
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...	...	...			3·37	
20	Potash (K_2O) as sulphate of potash ... 10	1,113	200	1,313	91·91			0·55	
	Mean ...	1,055	229½	1,284	\$ 89·88	+182	\$7·22	+\$5·52	+\$1·34
4	Nitrogen (N) as sulphate of ammonia ... 20	1,222	218	1,440	\$100·80			\$3·30	
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...	...	...			3·37	
15	Potash (K_2O) as sulphate of potash ... 20	980	176	1,156	80·92			1·10	
	Mean ...	1,101	197	1,298	\$ 90·86	+196	\$7·77	+\$5·59	+\$1·77
12	Nitrogen (N) as sulphate of ammonia ... 20	1,077	259	1,336	\$ 93·52			\$3·30	
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...	...	...			3·37	
19	Potash (K_2O) as sulphate of potash ... 30	1,059	139	1,198	83·86			1·66	
	Mean ...	1,068	199	1,267	\$ 88·69	+165	\$8·33	+\$3·22	–\$0·96

TABLE IV.

COTTON MANURIAL EXPERIMENTS AT CARLTON PLANTATION—LOWER MILL FIELD.

SIZE OF EACH PLOT = ·1705 ACRE. NITROGEN SERIES.

No. of Plot.	Manures used.		Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no nitrogen.
1 & 13	Nitrogen (N) as sulphate of ammonia	0	163	$11·41				
	Phosphoric acid (P_2O_5) as superphosphate ...	0	...	...				
	Potash (K_2O) as sulphate of potash	0	109	7·63				
	Mean, ...		136	$ 9·52				
2 & 14	Nitrogen (N) as sulphate of ammonia	0	152	$10·64				
	Phosphoric acid (P_2O_5) as superphosphate ...	60	...	...		$3·37		
	Potash (K_2O) as sulphate of potash	20	52	3·64		1·10		
	Mean ...		102	$ 7·14	−34	$4·47	−$6·85	

TABLE IV.—*Concluded.*

No. of Plot.	Manures used.		Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no nitrogen.
3	Nitrogen (N) as sulphate of ammonia	10	120	$ 8·40		$1·65		
&	Phosphoric acid (P_2O_5) as superphosphate ...	60	...	..		3·37		
15	Potash (K_2O) as sulphate of potash	20	80	5·60		1·10		
	Mean	...	100	7·00	– 36	$6·12	– $8·64	– $1·79
4	Nitrogen (N) as sulphate of ammonia	20	166	$11·62		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate ...	60	...	...		3·37		
16	Potash (K_2O) as sulphate of potash	20	83	5·81		1·10		
	Mean	...	124½	$ 8·71	– 11½	$7·77	– $8·58	– $1·73
5	Nitrogen (N) as sulphate of ammonia	30	156	$10·92		$4·95		
&	Phosphoric acid (P_2O_5) as superphosphate ...	60	...	...		3·37		
21	Potash (K_2O) as sulphate of potash	20	116	8·12		1·10		
	Mean	...	136	$ 9·52	0	$9·42	– $9·42	– $2·57

TABLE V.

Cotton Manurial Experiments at Carlton Plantation—Lower Mill Field.

Phosphate Series.

No. of Plot.	Manures used.		Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no phosphate.
1	Nitrogen (N) as sulphate of ammonia... … … …	0	163	$11·41				
&	Phosphoric acid (P_2O_5) as superphosphate … … …	0	…	…				
13	Potash (K_2O) as sulphate of potash … … … …	0	109	7·63				
	Mean …		136	$ 9·52				
6	Nitrogen (N) as sulphate of ammonia... … … …	20	137	$ 9·59		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate .. … …	6	…	…		…		
22	Potash (K_2O) as sulphate of potash … … … …	20	89	6·23		1·10		
	Mean …		113	$ 7·91	– 23	$4·40	-$6·01	

TABLE V.—*Continued.*

No. of Plot.	Manures used.		Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no phosphate.
7	Nitrogen (N) as sulphate of ammonia	20	144	$10·08		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate	20	...	...		1·12		
23	Potash (K_2O) as sulphate of potash	20	138	9·66		1·10		
	Mean ...		141	$ 9·87	+ 5	$5·52	– $5·17	+ $0·84
8	Nitrogen (N) as sulphate of ammonia	20	205	$14·35		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate	40	...	...		2·24		
24	Potash (K_2O) as sulphate of potash	20	166	11·62		1·10		
	Mean ...		185½	$12·98	+ 49½	$6·64	– $3·18	+ $2·83

TABLE V.—*Concluded.*

No. of Plot.	Manures used.	Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no phosphate.
1	Nitrogen (N) as sulphate of ammonia 20	166	$11·62		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate 60	...	...		3·37		
16	Potash (K_2O) as sulphate of potash 20	83	5·81		1·10		
	Mean ..	124½	$ 8·71	− 11½	$7·77	− $8·58	− $2·57
9	Nitrogen (N) as sulphate of ammonia 20	154	$10·78		$3·30		
&	Phosphoric acid (P_2O_5) as superphosphate 80	...	...		4·49		
17	Potash (K_2O) as sulphate of potash 20	99	6·93		1·10		
	Mean ...	126½	$ 8·85	− 9½	$8·89	− $9·56	− $3·55

TABLE VI.

Cotton Manurial Experiments at Carlton Plantation—Lower Mill Field.

Potash Series.

No. of Plot.	Manures used.		Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre. on no potash.
1 & 13	Nitrogen (N) as sulphate of ammonia	0	163	$11·41				
	Phosphoric acid (P_2O_5) as superphosphate	0	...	...				
	Potash (K_2O) as sulphate of potash	0	109	7·63				
	Mean ...		136	$ 9·52				
10 & 18	Nitrogen (N) as sulphate of ammonia	20	212	$14·84		$3·30		
	Phosphoric acid (P_2O_5) as superphosphate	60	...	...		3·37		
	Potash (K_2O) as sulphate of potash	0	104	7·28		...		
	Mean ...		158	$11·06	+22	$6·67	- $5·13	

TABLE VI.—*Concluded.*

No. of Plot.	Manures used.	Seed-cotton in pounds per acre.	Value per acre of seed-cotton at 7c. per lb.	Increase or decrease in pounds of seed-cotton by manuring per acre.	Cost of manure per acre.	Profit or loss by manuring per acre.	Profit or loss per acre on no potash.
11 & 19	Nitrogen (N) as sulphate of ammonia 20	474	\$33·18		\$3·30		
	Phosphoric acid (P_2O_5) as superphosphate 60	...	...		3·37		
	Potash (K_2O) as sulphate of potash 20	82	5·74		0·55		
	Mean ...	278	\$19·46	+142	\$7·22	+\$2·72	−\$7·85
4 & 16	Nitrogen (N) as sulphate of ammonia 20	166	\$11·62		\$3·30		
	Phosphoric acid (P_2O_5) as superphosphate 60	...	...		3·37		
	Potash (K_2O) as sulphate of potash 20	83	5·81		1·10		
	Mean ...	124½	\$ 8·71	− 11½	\$7·77	−\$8·58	−\$3·45
12 & 20	Nitrogen (N) as sulphate of ammonia 20	401	\$28·07		\$3·30		
	Phosphoric acid (P_2O_5) as superphosphate 60	...	...		3·37		
	Potash (K_2O) as sulphate of potash 30	95	6·65		1·66		
	Mean ...	248	\$17·36	+112	\$8·33	−\$0·49	+\$4·64

SHARE SYSTEM IN CANE CULTIVATION IN FIJI, HAWAII, AND MAURITIUS.

The following is a further contribution from his Excellency Sir Henry M. Jackson, K.C.M.G., on the subject of the Share System in Cane Cultivation adopted in Fiji, Hawaii, and Mauritius. This may be regarded as a continuation of the statement made by Sir Henry M. Jackson at the West Indian Agricultural Conference at Trinidad in January 1905 (published in the *West Indian Bulletin*, Vol. VI, pp. 18-21) :—

In the recent exhaustive inquiry held into the condition of the labour supply in Trinidad, it was made abundantly clear that the scarcity of labour pressed most heavily on the sugar industry, and that it was largely due to the fact that the overwhelming majority of indentured immigrants left the estates immediately on expiration of their term of service, and their labour was no longer available.

It was pointed out that the East Indians have been described as 'the most conservative peasantry on the earth' and that if some means could be devised of offering them comfort and independence in the district, where for five years past they had been forming many ties, it would probably afford a cheap and permanent remedy, by inducing them to remain on the estate. It is not to be expected of any free labourer, whatever his origin, that he will be content to continue working on the same terms as when under indenture, when there are so many openings for a more independent life and more prosperous occupation: but if he can find on the estates the means of making as much as he can elsewhere, and of leading his own life, it would be natural to him to remain among his friends. It is with the object of showing how these means have been devised and sucessfully worked elsewhere,

that the writer submits the following notes on the share system, worked by means of cane companies in Hawaii, Mauritius, and Fiji.

In Hawaii, the Commissioners of labour reported that in 1902 there was only one plantation on which the system had not been adopted, but that that estate was close to a large town and enjoyed special advantages in the way of local labour. It is true that the imported labour in Hawaii is Japanese, and that these men form the cane companies, but in Mauritius the conditions closely resemble those of Trinidad, and in Fiji the labour on the sugar plantations is almost exclusively Indian coolie immigration.

In Mauritius, at the commencement, considerable outcry was made by some planters when the land owned by others was first offered in small blocks to the coolies; but later many who had at first opposed the system, similarly offered their land, having recognized the great benefit to them of the change. The system was found on experience to lessen the annually recurrent heavy outlay for the introduction of new labour, besides cheapening the cost of the cane supplies, and ensuring the settlement in the vicinity of the mills of considerable numbers of free coolies, from whose ranks could be obtained contracting gangs for some of the harvesting and other work to be done during the crushing season, which work, if performed wholly by indentured labour, as formerly, necessitated the maintenance during the whole year of the maximum requirements of labour during any portion of the year, with the result that the cost of the crops was unduly burdened.

In Fiji, there was also considerable opposition at first among the managers of estates, and as the success of such innovations is largely dependent on the active sympathy of those entrusted with the administration of the details, the earlier results were somewhat disappointing. The proprietors were, however, convinced that the distrust could only be based on the absence of knowledge as to the actual effects, and insisted on the system being given a fair trial, with the result that it was found that the trouble was more apparent than real, and that the greater supervision as compared with the ordinary plantation duties of the overseers, which the work under the 'share system' required at the outset, rapidly became counterbalanced by the spontaneity of the work done, and by there being no need to measure up the individual tasks in each instance daily. The preliminaries, no doubt, necessitate a good deal of additional trouble, but the extra work is fully repaid by the sensible reduction in the cultivation expenses.

The 'share system' consists of the division of the land to be cultivated into blocks, a convenient size for which was found to be 60 acres. The land is prepared and planted by the estate, and the blocks are then handed over to cane companies, which may be composed of either free or indentured labourers, or both, and which carry on the cultivation under the supervision of the estate management. Until the cane is harvested the members of the cane company receive an advance of 1s. a day for each day of nine hours worked by such members,

such payments being afterwards deducted from the price paid for the canes. When the canes are cut and taken to the mill, the cane company is credited with the amount per ton agreed upon beforehand, and from this is deducted the advances made during cultivation, and the cost of any work done by the estate after handing over.

Attached are copies of the actual accounts of a cane company working a block of 60 acres on an estate in Fiji.

The block yielded 1,843 tons of cane, which, at 4*s.* a ton, gave the cane company a return of		£368 12*s.* 0*d.*
From which was deducted advances made for days worked... ...	£141 19*s.* 11*d.*	
Cost of stripping and loading (by estate)	8 18 11	
Hired labour for cutting (advanced cane company)	66 0 0	£216 18 10
		£151 13 2

There thus remained a balance of £151 13*s.* 2*d.* to be paid to the cane company, the members of which had worked approximately 2,595 days. This is equivalent to a bonus of 1*s.* 2*d.* a day, in addition to the 1*s.* a day already advanced, making their total earning 2*s.* 2*d.* a day. The block was not a specially good one, as on the same estate some cane companies earned as much as 3*s.* a head per diem, and in no case did they earn less than 2*s.*

Appendix B gives the actual cost to the estate of the canes of that block delivered at the mill, which is shown as 7*s.* per ton, including the cost of preparing and planting before the cane company took over the block, and of the laying of the portable tram line and of all the transport. It also includes a charge of 30*s.* per acre for supervision and maintenance, and a charge of 5*d.* per head per day worked for introduction and hospital expenses, though the actual cost of these was only 4*d.* per unit. It will be noticed that this is charged on the members of the cane company as well as on the estate coolies, and this is due to the fact that the whole of the members of No. 8 company, whose accounts are given, happened to be still under indenture.

Conditions are agreed to by the cane company, under clauses 1 and 7, by which a habitual idler could be got rid of, for not doing his work 'satisfactorily and in the manner directed.'

The money paid to the cane company, which, in case of the company shown in Appendix A, amounted to 2*s.* 2*d.* per head per day for 216 working days, must not be taken as representing the whole of their earning, as all the members had opportunity of gaining money in other ways. In fact, one of the problems to be solved, in order to make the system a success, is how to provide constant employment for the

members of cane companies, whose work on their block does not fill their whole time.

In the crop season there is no difficulty, as the members of the cane companies are also employed in the mills, and form part of the cutting gangs.

In order to set the men free for these purposes, the harvesting of the crop grown by the cane companies should be done by gangs of harvesters from amongst the members of these companies, who, under the direction of the estate management, cut and relieve the blocks in the rotation desired at a fixed rate per ton. This provides attractive earnings at work near at hand for the members of the cane companies, and as each cutter, or pair of cutters—for they usually work in pairs—is paid according to the tonnage of each truck, the men of the gang are as much on individual task work as when doing similar work under indenture. When the labour of any of these men is required on their own blocks, it is found easy to allow them to drop out for a few days without prejudice to the general interests.

Out of crop time many of those engaged in farming blocks devote a portion of their time to raising other crops on waste lands allowed them by the estate. A further means of overcoming the difficulty of providing the members of the cane companies with constant employment, and especially those still under indenture who have a right to demand it, is by allowing each company to take up two or three blocks, on which the operations requiring manual labour would be performed at different times, say, a block of early plants requiring much hand work, with a couple of blocks of ratoons cut early in the season. At odd times work may be found in connexion with the maintenance of tramlines, roads, formation and cleaning of drains, and permanent improvements.

In the Hawaiian agreements it is stipulated in almost every case that, when the estate is in need of labour, the cane companies shall furnish as many men as the estate may consider can be spared without prejudice to the cane companies' crops, such extra service being, of course, specially paid for.

In Fiji, the indentured labour readily came forward to work on the system outlined. At first, permission was only granted to those in their last six months of indenture, but it was very soon found desirable to extend it, as it became apparent that the indentured coolies working under the 'share system' were beginning to understand the advantages of growing canes for sale to the estates. Such experience is wholly absent from their ordinary conditions under indenture, and it appears reasonable to assume that when such coolies become free they will be more likely to continue to supply the estate than those who have worked under the much less heartening conditions of indentured service for five years, at their release from which, the sudden feeling of freedom is found to cause many to seek other pursuits locally, or decide to return to India.

It was universally admitted by those in charge of estates where the share system had been successfully established, that the canes were better tended than when the work formed portion of the daily task under indenture, and one of the principal managers in Fiji, a gentleman of lifelong experience among indentured labour in British Guiana, Australia, and the Pacific, was able to report in 1900 that the coolies working under the share system were doing double the task per day that any indentured man ever attempts to perform. A very practical result on the estates under his supervision was that in two years' time, although cultivation had increased, the percentage of indentured labour had decreased by almost 10 per cent., and this although the application of the system was still partial.

The writer feels very deeply his lack of anything approaching expert knowledge of the subject treated on, but the sugar industry in general, and indentured labour employed thereon in particular, have always been of special interest to him, and for some years he has been afforded exceptional opportunities of examining the difficulties which hamper them. These notes, which are the outcome partly of personal observation, and partly of discussion and correspondence with men who have faced and overcome these difficulties, are submitted in the hope that they may assist those with a better knowledge of local conditions, in adapting to those conditions a system which seems to go far to meet the advice given at the Labour Committee by a planter of large experience when he said, 'make a sort of friend of the immigrant so that when he has finished his time he will stick to the estate and not migrate.'

APPENDIX A.

Profit made by Planting Company.—

	£ s. d.	£ s. d.
1,843 tons of cane at 4*s*. ...		368 12 0
Work done by mill.—		
Stripping and loading ...	8 18 11	
Work done by Planting Co.—		
Hired labour for cutting ...	66 0 0	
Wages paid	141 19 11	216 18 10
Profit		£151 13 2

Approximate number of days worked, 2,595 = 1*s*. 2*d*. per day bonus; 1*s*. per day also paid for each day worked, thus making the total earnings of each member of planting company 2*s*. 2*d*. per day.

Blocks Nos. consist of 60 acres—30·7 tons per acre.

August 22, 1903.

APPENDIX B.

Planting Company No. Block No. (12 indentured men).

Cost of work done before planting company took over the fields, and of portable tramline and transport :—

	Units.	£	s.	d.
Ploughing out	183	5	2	9
Harrowing	27	1	4	0
Ridging	139	9	8	3
Drilling	24	1	14	0
Replanting	191	18	8	9
Scarifying	103	5	1	0
Ploughing between cane	39	2	12	6
Laying by	14	1	7	9
Portable tramline and transport ...	102	5	2	0
Scoops	144	6	12	0
	866	56	13	0
866 coolie units at 5*d*.		18	0	10
Live-stock Units Supervision, Maintenance, etc.				
289 Horse units at 1*s*. 7¼*d*. ...		23	18	0
466 Mule units at 1*s*. 0¾*d*. ...		24	15	1
898 Bullock units at 2½*d*.		9	7	1
Supervision, maintenance, etc., 60 acres at 30*s*.		90	0	0
2,595 Indentured units of planting company, at 5*d*.		54	1	3
1,843 tons cane at 4*s*. per ton ...		368	7	3
		£645	7	3

Total cost of cane, £645 7*s*. 3*d*.; tons cut—1,843—7*s*. per ton.

AGRICULTURAL CREDIT IN GERMANY.

The following article appeared in the *Journal of the Board of Agriculture*, for March 1906. It contains much information which is of interest in connexion with the proposal to establish agricultural banks in the West Indies. This question was discussed by the Hon. Wm. Fawcett, B.Sc., F.L.S., in a paper read before the West Indian Agricultural Conference held in Trinidad in January 1905:—

The spread of co-operative ideas in Germany during recent years has been very marked, and nowhere, perhaps, have they been received with more favour than in the agricultural world. In 1888, there were 4,821 co-operative societies of all kinds, ten years later this number had increased to 16,069, while, according to the *Statistisches Jahrbuch*, they numbered 23,221 on January 1, 1905, with a membership of 3,409,871. These included 14,272 co-operative credit societies with a membership of 1,901,000; 1,595 societies for the purchase of agricultural requisites, 3,062 societies for the manufacture of dairy and other products, 682 other agricultural societies, while the remainder were industrial and other societies not distinctively agricultural.

Credit societies, it will be seen, represent the most popular form of co-operation, and account for 61 per cent. of the societies and 56 per cent. of the total membership.

Some part of the success which has attended their formation in Germany may be attributed to the financial support obtained by the formation of central banks devoting themselves more or less exclusively to co-operative business.

The development in this direction, which has not previously been dealt with in this journal, possesses many features of interest.

There are two classes into which the credit banks may broadly be divided: those founded on the Schulze-Delitzsch system and those based on the Raiffeisen principle. The difference between them has been frequently explained, and it will be sufficient here to indicate the distinction somewhat briefly.

SCHULZE-DELITZSCH BANKS.

The Schulze-Delitzsch credit societies were designed by their founder, after whom they are named, mainly for the benefit of mechanics and small tradesmen. They grant loans on promissory notes and bills for short periods of from three to nine months, and at the same time encourage their members to deposit their savings with the society.

At the time of their foundation they rested on the principle of unlimited liability, but in later years limited liability was also introduced, especially as their accumulations of capital increased. Unlimited liability and self-help were, however, declared by Schulze in 1858 to be the only principles justifiable in economy, and, moreover, 'particularly suitable to the character and manners of our people.' As a matter of fact,

the collective liability of the members to the extent of their whole means was at that time the only system recognized by the law, but by an Act passed in 1889, the limited liability of members was admitted. A new form of unlimited liability, by which the member's risk was rendered more remote, was also introduced but has been but little adopted.

In the Schulze-Delitzsch societies, every member subscribes a certain share of the capital, no one being allowed to exceed a certain limit. This is payable in one sum or in monthly instalments. Loans are granted to members only, without inquiry as to the purposes for which they are required, on security, which may take the form of mortgages, guarantee by another member, bills, etc. They are only granted for short terms, and this is one of the features which distinguish these associations from those on the Raiffeisen principle. Deposits are received both from members and from other persons, and these, together with the small capital, form the fund from which loans are made, while the credit due to the unlimited liability of the members enables these societies to raise any money which may be required in addition. The societies are usually established in towns, but are open to any one, regardless of place of residence.

The rate of interest on loans demanded by these banks is higher than that required by the Raiffeisen associations and they are not so generally adapted to agricultural requirements as the latter. It would be a mistake, however, to suppose that they do nothing for agricultural credit, as, according to the figures of 1902, 28½ per cent. of the members were peasants and farmers, 24½ per cent. mechanics, and 10 per cent. merchants and dealers. The number of societies belonging to the Schulze-Delitzsch Union was 899 with 533,888 members.

RAIFFEISEN BANKS.

The loan and savings banks founded by Raiffeisen may be said to have three main objects: (1) to encourage thrift among the agricultural population; (2) to satisfy the demand for loans on personal security; and (3) to act as bankers in the country district. They rest, to an even greater extent than the Schulze-Delitzsch societies, on the principle of solidarity or unlimited liability, in that practically no share capital is raised, the money for working the society being obtained from entrance fees, subscriptions, and deposits, and borrowed from persons outside the society on the collective security of the members. Loans are advanced only for reproductive purposes, evidence being required for a reasonable prospect of repayment at the date fixed, and they must be guaranteed by another member of the society. The operations of these societies are limited to small areas, usually a village or small town, so that the personal character and circumstances of applicants for loans may be known to the members and committee. The administration is honorary, no salary being paid (except a trifling sum to the secretary), and all profits realized go to a reserve fund.

BANKS WITH LIMITED LIABILITY.

The foregoing classes of associations depend on the joint and several liability of the members for any losses incurred by them, but since the passing of the Act of 1889 the establishment of co-operative societies with limited liability has become possible. The system has of late been more largely adopted, and at the beginning of 1905, there were 1,623 credit societies with a membership of 356,000 on this basis, out of a total of 14,272 societies. Societies of this class exist to a considerable extent in Pomerania and Prussian Saxony, where the principle of unlimited liability has not been regarded with favour. Dr. O. Rabe observes that in Prussian Saxony, 'where there is a mixture of large, medium, and small properties, unlimited liability is not suitable, as it puts too heavy a burden on the man of property for the benefit of those of smaller means. The view that unlimited liability confers greater authority and credit on co-operative societies is not correct. For what does a co-operative society with unlimited liability represent when, as a general rule, only persons of small means have joined as members?'

The German system of limited liability as applied to co-operative societies differs, however, in some respects from the English conception of limited liability. The amount of shares and liability guarantee to be taken is not left to the free will of the members, but compulsorily apportioned to the means of the individual members; thus, members are required to take one share for every £100 for which they are assessed to property tax, and for every share they must undertake a guarantee of £10. That is, they go bail for the liabilities of the society to the extent of one-tenth of their possessions. The credit accorded to each individual member is measured by the amount of his guarantee. Thus a member holding fifty shares guarantees the liabilities of the society to the extent of £500, but he will not be allowed credit for £500, but only for about £375, without further security, and for advances beyond this sum he must give a bill or personal sureties. Dr. Rabe, writing in 1901, observes that during the twelve years these banks have been in existence none have failed, no losses whatever have been recorded in connexion with them, and they have rapidly gained the confidence of the population. The value of each share is put at 5*s*.

CENTRAL BANKS.

It will be understood that the first need of these societies, whether Schulze-Delitzsch, Raiffeisen, or limited liability, was to borrow money on the cheapest terms, and afterwards, as their reserves and deposits accumulated, to arrange some means whereby any balance in the hands of one society could be used to satisfy the wants of another. From a very early period, therefore, the need of a central organization began to be realized. Isolated from each other, and, in the case of the Raiffeisen banks, necessarily confined to small areas, with correspondingly small funds, they were hardly in a position to fulfil the expectations entertained of them, and a consolidated

body was felt to be a necessity. With this object provincial central banks were formed by combinations of societies, and some of these were afterwards affiliated to still larger institutions, such as the central bank of Neuwied. It will be easily understood that the centralization of co-operative banking was a matter of some complexity, and that the measures taken by the various societies were by no means uniform. A detailed description will be found in a series of reports presented to the International Co-operative Congress at Budapesth, to which those interested in the subject should refer. The following general summary indicates, however, some of the main features :—

THE CENTRAL BANK OF NEUWIED.

In the case of the Raiffeisen societies, the first central bank was formed at Neuwied, in Rhenish Prussia, in 1872, by eleven societies. In 1876, it was reformed as a joint-stock company with a share capital of £12,500, which was gradually raised until, in 1900, it stood at £500,000, of which £415,000 had been paid up in cash by 3,754 affiliated societies.

This organization, known as the 'Landwirtschaftliche Centraldarlehenskasse für Deutschland,' besides carrying on the business of a banker, also buys agricultural requisites and sells produce for the benefit of its societies. The funds required are provided by (1) the share capital ; (2) the deposits received, or loans raised if possible for long terms ; (3) the commissions charged and the margin of interest ; (4) proceeds of the sale of goods ; and (5) bonds and debentures not made redeemable at will. These funds are employed for advances in current account to the branch banks and societies which are members, as working capital in the sale and purchase business, and for discounting bills and advancing money on security.

Business between the bank and its societies is conducted by branch banks, but every share-holding society is directly represented at the general meeting, which elects the board of directors. Each district in which there is a branch bank has its own advisory board and local committee of management, as well as managing directors of the branch banks. The latter are on the committee of management of the central bank.

The co-operative character of the central bank is maintained by restricting the dividend to 4 per cent. on the paid-up capital, which goes only to the co-operative societies which are members, the balance remaining being carried to reserve.

Each branch bank may give credit to a society up to 10 per cent. of the property of its members, and the main business of the central institution is to equalize the supply and demand of money, which is done in this way : should a branch bank require money it telegraphs to the central bank, which at once assigns to it funds at its banking account with the Prussian Central State Bank. Excess cash held by the branches is in the same way paid to the credit of the central bank.

The magnitude of the operations of this institution may be gathered from the fact that the turnover in 1903 amounted to

£15,350,000, and the assets to £3,240,000. The profits only amounted to £12,000, out of which a dividend of 3 per cent. was paid.

OTHER CENTRAL BANKS.

In addition to the twelve local central banks acting as branches of the central bank of Neuwied, there are twenty-two provincial central banks affiliated to the Union of German Agricultural Co-operative Societies, presided over by Dr. Haas, of Darmstadt, and in addition some half a dozen central banks outside the Union. These banks represented approximately 8,500 societies, but this number includes some societies other than credit societies, which, taken by themselves, probably number about 7,300. Each of the central banks, however, forms a separate entity, the action of the Union being confined to audit and inspection.

Briefly, these central banks have adopted the system of limited liability referred to above, viz., that of issuing small shares carrying a comparatively heavy liability, and the credit allowed by them to their affiliated societies varies, but bears a relation to this liability, generally in excess. The working funds are derived from the small share capital, from deposits, and from the Prussian Central State Bank, which advances them money on the security of their members' liability to an amount not exceeding ten times the paid-up share capital. According to figures quoted by Herr Heuzeroth, in an article prepared for the Sixth Congress of the International Co-operative Alliance, the share capital of the twenty-two banks within the Union amounted to £213,000 and the loan capital to £2,897,000, made up of drafts on the State Bank, £654,000, and deposits from local societies, about £2,000,000.

It may be noted that during the past year an amalgamation has taken place between the Darmstadt Union and the Raiffeisen organization at Neuwied, by which the supreme control of both organizations will be vested in a central committee. The terms of the union have been so arranged as to secure the continued existence within it of the special institutions of the Raiffeisen type.

THE GERMAN CO-OPERATIVE SOCIETIES BANK.

It will be seen that the central banks above described, both that at Neuwied and those affiliated to the Darmstadt Union, obtain credit by pledging the combined liabilities of the societies which they represent. In the case of the Raiffeisen banks, represented by the first-named institution, the liability of all the members of all the societies to make good the debts of the central body is unlimited; in the case of the second class of central banks, the liability of the societies is limited to the amount of their guarantee. The principle, however, never met with the approval of societies of the Schulze-Delitzsch type, which took the view, that a central bank should be an independent institution whose actions would not, under any circumstances, jeopardize the welfare of the societies. With this object the German Co-operative Societies Bank was formed as

a joint stock company in 1864, with a capital of £40,000, which was gradually increased to £1,500,000. Its operations have not been confined to credit societies, though it naturally made a special feature of co-operative banking, and its essential principle has been that it dealt with the Schulze-Delitzsch banks without favour on distinctly business lines. As may be gathered from its increase of capital, it met with very considerable success, but the extension of banking business in Germany made its amalgamation with some more powerful institution desirable, and it has recently been absorbed into the Dresdener Bank.

THE PRUSSIAN CENTRAL STATE BANK.

It now only remains to notice the action taken by the Prussian Government for the assistance of co-operative banking by the foundation in 1895 of the Prussian Central State Bank. The funds placed at its disposal were at first £250,000, which were increased in 1896 to £1,000,000, and in 1898 to £2,500,000. Dr. Heiligenstadt, the President of the bank, in a memorandum on the subject, thus explains the view taken by its promoters: 'When dealing with co-operative organizations, even by the comparatively easy method of current accounts, the great banking institutions of the country obviously cannot forego the condition of demanding adequate bankable security. Bankable security, however, is just what co-operative institutions are rarely in a position to supply to any considerable amount, because in co-operative institutions the formation of capital or pledgeable assets is by the very nature of things slow, and need is sure to be greatest where such formation is least developed. And this hindrance may be said to hamper even societies of old standing, in which the creation of capital has been in progress for some time, and which have, as a rule, succeeded in some measure in adapting themselves to the requirements of the banking market. In more recently formed societies, more particularly in agricultural districts, the obstacle is painfully in evidence. Such societies are only very rarely in a position to satisfy bankers' requirements at all. The Prussian Central State Bank was formed to bridge over the existing chasm and bring demand and supply together by interposing between them a powerful institution, which, having no selfish interest of gain or profit to study, might be employed to satisfy the need of personal credit on reasonable conditions in the case of the lower and middle classes, when combined for productive purposes in co-operative societies.'

The State Bank only advances money, except on tangible security, to unions of co-operative societies, such as central banks, etc., and not to individual societies. In the case of unlimited liability societies, the advances are limited to 10 per cent. of the total value of the property involved, and in the case of limited liability to something less than the actual sum guaranteed.

At the close of March 1904, the bank had business relations with fifty-two central banks, nineteen of which were mainly urban and industrial, representing 405 societies and

80,563 members, while thirty-three were rural and agricultural, representing 8,940 societies and 807,101 members. The balance sheet showed that it held £393,664 on current account and £1,370,684 on deposit, and had £1,877,118 outstanding for advances on bills of exchange, etc.; the net profits amounted to £110,000, or 4·41 per cent. on the capital. The bills discounted in 1903 amounted to £3,957,000.

In several other German States, i.e., Bavaria, Saxony, and Wurtemberg, the Governments, without actually establishing state banks, have given subventions or some form of financial assistance to a central co-operative bank, and claimed a reasonable amount of representation in the management.

MANURIAL EXPERIMENTS WITH CACAO IN GERMAN WEST AFRICA.

In connexion with the manurial experiments conducted in Dominica, the results of which were published in the last issue of the *West Indian Bulletin* (pp. 201-12), it may be of interest to place on record for the benefit of cacao planters in the West Indies the results of similar experiments in German West Africa.

Dr. L. Strunk, of Victoria, Cameroons, contributed to the *Tropenpflanzer*, for August 1906, an account of a carefully carried out scheme of manurial experiments with cacao. This account, it should be pointed out, deals with the results of one year's experiments only. It is probable that the beneficial results of a rational system of manuring will be even more visible after two or three years. The cumulative effects of manures, in the case of permanent crops like cacao, are not, of course, brought out in one season's experiments.

Dr. Strunk clearly shows that profit may be expected to accrue from properly conducted manurial experiments with cacao. The use of a complete manure on Victoria cacao in 1905 produced a profit of 1*s.* 6½*d.* per tree, while an application of phosphate and potash resulted in a gain of 1*s.* 4*d.* per tree. It was not found possible to test the effect of heavy applications of pen manure or compost, these not being obtainable in sufficient quantities.

Turning now to the results reported recently from Dominica, it is found that a complete manure produced there a profit of about 1*s.* 3*d.* per tree, while the application of phosphate and potash resulted in a loss of about 7*d.* per tree. The most striking results were obtained by mulching with leaves and grass, a gain of 3*s.* 2¼*d.* per tree being recorded.

There is a noticeably low yield from the cacao trees in these West African experiments. The Dominica trees give nearly three times the yield of the Amelonado variety in the Cameroons. This difference is mainly due to the prevalence of *Phytophthora* in the Cameroons; also, probably, in part, to the greater age of the trees in the experiment plots.

The following is a translation of Dr. Strunk's article in the *Tropenpflanzer*:—

Professor Wohltmann's numerous and thorough analyses of the soils of the Cameroons have been the basis upon which certain districts have been selected as specially suitable for the planting of cacao. These districts lie on the southern and western slopes of the Cameroon mountains. The success of the cacao plantations started there fully confirms the theoretical conclusions.

The prevailing soil of Victoria is certainly one of the best hitherto known on the West Coast. When rightly planted, cacao succeeds excellently there at first, but its early energetic growth seems soon to cease. Trees ten to twelve years old fail in strength and readily succumb to their numerous enemies, from which, in the Cameroons, it has not yet been found possible to protect them. In the experimental gardens it was noticed also that the yield, especially of certain varieties, began to decrease at an earlier age than in other tropical lands.

Manurial experiments on old trees of different varieties were needed to demonstrate what constituents of plant food were required in case it became absolutely necessary, in consequence of decreased yield, to apply manures on a large scale.

On account of the large extent of the plantations, pen manure and compost could seldom be obtained in sufficient quantities. Hence these were left out of consideration in the manurial experiments, which were confined to chemical fertilizers.

The manures were applied to the trees in the experimental plots in October and November 1904. This time was chosen because it was just after the chief rainy season and there were still some months before the dry season. Hence, there would be enough rain to dissolve the manures, but not so much as to wash them out, or, in the case of some, e.g., ammonia salts, to prevent their proper action. The cacao had been planted in 1895. One part was planted with the variety called Amelonado, a variety which has been commonly cultivated in Victoria, Cameroons, for a long time; the other part contained Trinidad cacao from St. Thomé, which, however, was not a uniform variety. The Amelonado cacao was planted 13 feet by 13 feet apart and received the smaller dressing of fertilizer: the Trinidad cacao was $16\frac{1}{4}$ feet by $16\frac{1}{4}$ feet apart and was given the heavier application of chemicals. Neighbouring cacao trees of both varieties were left unmanured for comparison. The Victoria cacao (Amelonado) was manured as follows:—

1. Thirty-three trees; to each tree:—
   - 2·2 lb. slaked lime,
   - 2·2 lb. kainite,
   - 1 lb. superphosphate,
   - ½ lb. sulphate of ammonia.
2. Twenty-five trees; to each tree:—
   - 2·2 lb. kainite,
   - 1 lb. superphosphate,
   - ½ lb. sulphate of ammonia.
3. Twenty-nine trees; to each tree:—
   - 2·2 lb. kainite,
   - 1 lb. superphosphate.
4. Twenty-seven trees; to each tree:—
   - 2·2 lb. kainite,
   - ½ lb. sulphate of ammonia.
5. Twenty-nine trees; to each tree:—
   - 1 lb. superphosphate,
   - ½ lb. sulphate of ammonia
6. Twenty-seven trees; to each tree:—
   - 2·2 lb. slaked lime,
   - 2·2 lb. kainite,
   - 1 lb. superphosphate.
7. Twenty-eight trees; to each tree:—
   - 2·2 lb. slaked lime,
   - 2·2 lb. kainite,
   - ½ lb. sulphate of ammonia.

One hundred and sixteen trees were left unmanured.

The analysis of the soil of this part is as follows:—

	First 19½ inches. Per cent.	Second 19½ inches. Per cent.
Moisture	14·49	12·27
Loss on heating to redness ...	11·31	10·96
Nitrogen	0·133	0·127
Soluble in cold hydrochloric acid.—		
Iron oxide	13·967	14·892
Alumina	14·324	17·413
Silica	0·989	0·658
Lime	0·321	0·309
Magnesia	0·217	0·263
Phosphoric acid	0·123	0·145
Potash	0·040	0·051
Soluble in hot hydrocholoric acid.—		
Potash	0·075	0·070

The manures which were applied to the Trinidad cacao were as follows :—

1. Twenty-five trees ; to each tree :—
   3·3 ℔. slaked lime,
   3·3 ℔. kainite,
   1·7 ℔. superphosphate,
   0·8 ℔. sulphate of ammonia.
2. Twenty-seven trees ; to each tree :—
   3·3 ℔. kainite,
   1·7 ℔. superphoshate,
   0·8 ℔. sulphate of ammonia.
3. Twenty-eight trees ; to each tree :—
   3·3 ℔. kainite,
   1·7 ℔. superphosphate.
4. Fifty-four trees ; to each tree :—
   3·3 ℔. kainite,
   0·8 ℔. sulphate of ammonia.
5. Twenty-seven trees ; to each tree :—
   1·7 ℔. superphosphate,
   0·8 ℔. sulphate of ammonia.
6. Thirty trees ; to each tree :—
   3·3 ℔. slaked lime,
   3·3 ℔. kainite,
   1·7 ℔. superphosphate.

Fifty-seven trees were left unmanured for comparison.

Soil analysis gave the following results for this part :—

	First 19½ inches. Per cent.	Second 19½ inches. Per cent.
Moisture	15·57	14·92
Loss on heating to redness ...	11·45	10·94
Nitrogen	0·179	0·150
Soluble in cold hydrochloric acid.—		
Iron oxide	12·70	16·84
Alumina	16·71	18·78
Silica	1·113	1·062
Lime	0·223	0·254
Magnesia	0·146	0·204
Phosphoric acid	0·140	0·185
Potash	0·047	0·050
Soluble in hot hydrochloric acid.—		
Potash	0·085	0·078

The fertilizers (except the lime) were well mixed together, and the mixture was measured out for each tree with a tin cut to the proper size. The lime was applied separately. The dead leaves on the ground had been previously raked into heaps. No

fertilizer was put within a radius of about 3 feet from a tree, but the rest of the soil between the trees was evenly manured. The soil was worked, after the fertilizers had been spread, to a depth of 4 inches. Some heavy showers fell in November, after all the fertilizers had been applied, and aided their operation.

The blossom of the cacao has usually set fruit in Victoria towards the end of January or the beginning of February. To determine the effect of the manures on this crop, the returns of cacao from April 25 were weighed for each tree. It was, of course, impracticable to ferment and dry the cacao beans for each tree separately. So the beans just out of the rind, together with the pulp, were weighed from each separate group of similarly manured trees. Also from several experiments the average amount by which this weight exceeded that of the fermented and dried beans was determined. It was found that fresh beans with the pulp lost 60·6 per cent. on fermenting and drying.

Tables I and II give the average results for a tree of each group, for each month. The average crop for the year from one tree is also given, and by subtracting 60·6 per cent. for loss in fermentation and drying, the amount of prepared cacao has been calculated.

What definite results proceed from these experiments? We notice from Table I that the fertilizers have, in every case, greatly increased the amount of pods on the Victoria cacao. From Table II we see that the fertilizers have not had so much influence on the year's output of Trinidad cacao. But in reality the comparison is only fair, for the latter, from April to August. After the latter month, we notice in September that many of the Trinidad cacao control trees reached their maximum later than the manured trees. We have already mentioned that this cacao is not a uniform variety, and so the trees differ in the months in which they ripen most pods. This lateness of ripening in part of the control plants brought their late fruit into the dry season, and very little of it was then destroyed by the *Phytophthora* fungus. Before September a tolerably large percentage of all pods was lost through this disease. (It has been proposed, by selection of the later individual varieties, to delay the maximum fruiting of the cacao until the dry season, at which time the spreading of the *Phytophthora* can be hindered. But, in the region of the Cameroon mountains, there is the difficulty that when seeds of cacao are sown in the dry season, the plants cannot live for lack of water.)

In Table I, for Victoria cacao (Amelonado), we notice that, in three cases, the fertilizers more than trebled the yield. These are Nos. 2, 3, and 7. With Trinidad cacao, also, (although the heavier manuring showed a smaller result), Nos. 2 and 3 are the best. No. 3 was manured with potash and phosphoric acid, and the same two fertilizers, with nitrogen added, were applied to No. 2.

In both series of experiments, potash and nitrogen gave a smaller result than other mixtures, but they had a better effect when lime was previously applied. (No. 7, Table I.)

TABLE I.

VICTORIA CACAO.

Months. 1905.	No. of days pods were gathered.	Average production of the single trees of the individual experiment plots in pounds.							
		No. 1. (33 trees.)	No. 2. (25 trees.)	No. 3. (29 trees.)	No. 4. (27 trees.)	No. 5. (29 trees.)	No. 6. (27 trees.)	No. 7. (28 trees.)	Control. (116 trees.)
April	1	·03	·20	·23	·29	·20	·38	·29	·20
May	4	·69	·93	1·34	1·31	1·09	1·05	1·07	·56
June	4	·93	2·19	3·30	1·36	1·40	1·32	1·48	·48
July	4	2·11	4·21	2·42	2·23	2·68	2·27	2·38	1·05
August	3	3·59	3·94	3·14	2·45	3·52	3·59	4·40	1·05
September	2	1·90	1·43	·99	·48	·70	1·10	1·73	·26
October	2	·35	·47	·25	·10	·23	·17	·51	·06
November	1	·03	·11	·08	—	·02	—	·02	·004
Total average weight per tree of unfermented cacao in one year	...	9·6	13·5	11·8	8·2	9·8	9·9	11·9	3·7
Total average weight per tree of cacao ready for market (calculated) ...	...	3·8	5·3	4·7	3·2	3·9	3·9	4·7	1·3
Essential constituents of fertilizers...	...	Ca	—	—	—	—	Ca	Ca	—
		K	K	K	K	—	K	K	—
		P	P	P	—	P	P	—	—
		N	N	—	N	N	—	N	—

TABLE II.

TRINIDAD CACAO.

Months. 1905.	No. of days pods were gathered.	Average production of the single trees of the individual experiment plots in pounds. No. 1. (25-23 trees.)	No. 2. (27 trees.)	No. 3. (28 trees.)	No. 4. (54 trees.)	No. 5. (27 trees.)	No. 6. (30 trees.)	Control. (57 trees.)
April	1	·10	·09	·48	·25	·12	·27	·29
May	4	·51	·49	·74	·37	·61	·56	·61
June	4	·79	·46	·92	·30	·12	·10	·10
July	4	·59	·73	·80	·22	·49	·38	·59
August	3	1·07	1·06	·90	·63	1·21	1·15	·62
September	2	·44	1·19	·79	·72	·49	·43	·97
October	2	·35	·68	·69	·41	·15	·17	·25
November	1	·05	·03	·07	·06	—	·03	·03
Total average weight per tree of unfermented cacao in one year ...	...	4·0	4·7	5·4	3·0	3·2	3·1	3·5
Total average weight per tree of cacao ready for market (calculated) ...	...	1·6	1·9	2·1	1·3	1·3	1·2	1·4
Essential constituents of fertilizers	..	Ca	—	—	—	—	Ca	—
		K	K	K	K	—	K	
		P	P	P	—	P	P	—
		N	N		N	N		—

Although in No. 3 of Table I (potash and phosphate) the crop was trebled, no effect at all on the growth of the trees could be noticed. But in No. 2 of Table I (potash, phosphate, and nitrogen) there was a remarkable increase in the growth. This latter mixture has also been tried, with good effect, on some six-year-old cacao trees whose growth was poor, probably because they grew in a tract previously used by the natives for growing provisions.

I have come to the conclusion that mixture No. 3 is the fertilizer required to increase considerably the production of old cacao trees, while mixture No. 2 (with ammonia) will increase the growth of backward trees. This mixture No. 2 would be suitable to apply when old trees have been injured by insects.

How much net gain is there from the best results?

By Experiment 2, Table I, one tree had :—

2·2 ℔. kainite (at 8*s*. for 220 ℔. and 4*s*. freight)	1·4*d*.
1 ℔. supherphosphate (at 10*s*. for 220 ℔. and 4*s*. freight)	0·8*d*.
⅝ ℔. sulphate of ammonia (at 33*s*. for 220 ℔. and 4*s*. freight)	1·1*d*.
	3·3*d*.

The cost of the manures used in Experiment 2, without reckoning cost of application, comes to 3½*d*. per tree.

Dry cacao from manured tree	5·3℔.
" " " unmanured tree	1·3℔.
Increase through manure	4℔.
At 5½*d*. per ℔., this is worth	1*s*. 10*d*.
The cost of the manure is	3½*d*.
Net gain per tree by manuring	1*s*. 6½*d*.

In Experiment No. 3, Table I, the manure cost less, since sulphate of ammonia is omitted, bringing the expense of manuring to less than 2½*d*. per tree.

Average crop of dry cacao from each manured tree	4·7℔.
Average crop of dry cacao from each unmanured tree...	1·3℔.
Increase by manuring	3·4℔.
At 5½*d*. per ℔., this is worth	1*s*. 6½*d*.
The cost of this manure is	2½*d*.
Net gain per tree by manuring	1*s*. 4*d*.

The cost of application must also be deducted here.

These favourable results may perhaps lead to increased interest being taken in manurial experiments with cacao. They may perhaps stimulate those in charge of large plantations to undertake such experiments on a small scale, and so to learn what mixture and quantity of fertilizers will be pecuniarily profitable in each special case. This important knowledge can be gained only in one way, viz., by actual trial.

CITRATE OF LIME.

The attention of West Indian planters was first drawn to the question of the manufacture of citrate of lime for export in place of concentrated lime juice by Dr. Francis Watts in 1898 in a paper published in the *Bulletin of the Botanical Department*, Jamaica (Vol. V, pp. 263-9). In this paper, which was reproduced in the *West Indian Bulletin* (Vol. II, pp. 308-18), Dr. Watts pointed out that, owing to the high cost for freight and packages entailed in the shipment of raw lime juice, containing from 10 oz. to 15 oz. of citric acid per gallon, efforts were made to obtain the citric acid in a more concentrated form.

The usual method adopted in the West Indies was the concentration of the juice by boiling. There still remained, however, the objection of having to ship a bulky liquid product, which necessitated expensive packages and heavy charges for freight. It was suggested that this objection might be removed by producing the solid citrate of lime. For a long time this idea had been afloat, but only during the last few years had it been acted upon with any degree of success. The production of citrate of lime had become an established industry in Italy and Sicily, where the exportation of this product had largely taken the place of that of concentrated lemon juice. The imports of citrate of lime into the United States had increased from 42,558 ℔. in 1887 to 1,026,467 ℔. in 1898.

Dr. Watts then proceeded to describe the process of manufacturing citrate of lime, and his description may be summarized as follows :—

Owing to the presence of a large quantity of gummy impurities in lemon or lime juice, the active principle, viz., citric acid, will not separate out in the form of crystals when the juice is simply concentrated, as does cane sugar when cane juice is concentrated. In order to overcome this difficulty, the citric acid in the juice is converted, by the addition of chalk, into insoluble citrate of lime, which is separated by subsidence and straining through linen.

The juice having been placed in a suitable mixing vessel, a creamy mixture of chalk and water is added with constant stirring until the acid is neutralized. The mixture is then heated to cause the citrate of lime to become crystalline and to subside rapidly. The heating is then stopped, and the super-

natant, clear, yellow liquid is poured or syphoned off. With a view to removing the gummy matters, which cause the citrate to cake in drying and may give rise to a darkening in colour, the citrate is washed several times with hot water.

The next stage consists in the removal of the water from the citrate. For this purpose, the latter is thrown upon a cloth strainer, when only a small quantity is being made, or, on a larger scale, placed in a special filter. This operation might well be carried out by means of filter presses.

Next comes the drying process. This requires special care and is attended by considerable risk of loss. The citrate of lime should be brought quickly into some form of drying apparatus where a temperature of 150° to 200° F. can be maintained, while there is at the same time a free circulation of air through the chamber in order to carry away the moisture.

When prepared in the manner described, citrate of lime is a white powder, free from hard lumps. If kept in a dry place, it will remain good indefinitely. For shipment it should be tightly packed in paper-lined barrels. It should contain over 60 per cent. of citric acid.

The practical difficulties likely to arise in the manufacture of citrate of lime were referred to by Dr. Watts as follows:—

In the first place the chalk employed must be of very first quality, free from magnesium salts and from more than a trace of iron, alumina, and phosphates. The chalk must also be of such a quality that it can be readily mixed into a cream with water. It might be possible to use slaked lime, but in this case care would have to be taken not to neutralize the juice completely, as this would result in the precipitation of impurities with the citrate, which would interfere with the subsequent manufacture of the latter.

Next comes the difficulty of ascertaining when the exact point of neutralization is arrived at. Tests would have to be adopted for this purpose.

The advantages of citrate of lime over concentrated juice, from the citric acid manufacturer's point of view, were summed up by Dr. Watts as follows:—

'It can be stored without loss, while juice is liable to leak from the casks. The first stage of the manufacture of the acid has been already completed and the manufacturer can dispense with the neutralizing vats and the filters: thus there is much economy of space and of labour. Finally, owing to the fact that citrate of lime is white, while concentrated juice is black, from the charring action of the heat used in its production, the resulting citric liquors obtained from citrate are of a better colour, yielding whiter crystals of citric acid, thus reducing the operations of refining the citric acid and saving both labour and material.

'Possessing these advantages, it seems probable that citrate of lime will ultimately displace concentrated juice, provided that an article thoroughly suited to manufacturers' requirements is produced: as competition becomes keener in the production of raw material—and this is likely to ensue

from the attention being given to tropical products and the difficulty experienced in finding new and profitable ones—there will arise competition between these two forms of raw material, when the preference which the manufacturer of citric acid will give to well-prepared citrate will, no doubt, enhance its value in comparison with concentrated juice. Hitherto, the production of citrate of lime has been relatively small, so that competition between the two forms of raw material can hardly be said to exist. It is not unlikely that this condition may be altered in the near future.'

Some years later, viz., in 1902, (see *West Indian Bulletin*, Vol. II, p. 316), Dr. Watts stated that, provided attention were paid to the thorough removal of colouring matter, 'and a well-prepared and well-washed citrate, free from impurities, is put on the market, there is little doubt that, in a short time, it will command a better and readier sale than its competitors.'

'As regards price,' said Dr. Watts, 'citric acid, whether in the form of concentrated juice or of citrate of lime, has practically the same market value. Citrate of lime is quoted in terms of the standard cask of 305 kilos. (675 ℔.), containing 64 per cent. of citric acid; a standard cask therefore contains 430½ ℔. of acid. Concentrated juice is quoted in terms of the pipe of 108 gallons, containing 64 oz. of citric acid per gallon, being equivalent to 432 ℔. of acid; the quantities are practically identical. At present these two commodities command approximately equal prices; sometimes one, sometimes the other having a slight advantage.'

On May 24, 1904, Dr. Watts gave, for the benefit of the members of the Dominica Agricultural Society, a practical illustration at the Bath estate of the methods involved in the manufacture of citrate of lime. Later in the day he gave the following *résumé* of what took place, which is reprinted from the *Dominica Agriculturist* (No. 3):—

During the whole of the day we have been trying to put into practice the essential features of the process of making citrate of lime, which appeared in the *West Indian Bulletin* (Vol. II, no. 4). As you are well aware, citrate of lime is what the manufacturers make out of concentrated lime juice as the first step in the manufacture of citric acid. To make sugar, you boil down cane juice to a certain point and leave the principal constituent to crystallize. When you boil down lime juice you do not get crystals, as there are gums and other impurities which prevent that. You have to remove these, so citrate of lime is made as an intermediate stage. There is no virtue in the concentration of lime juice; in fact, it is rather spoiled by the fact that it turns black. Concentration is only done to reduce bulk and save freight. The manufacturer, on receiving this concentrated juice, dilutes it with water to about its original strength when raw, and then makes, by the addition of chalk, citrate of lime, just as we have done to-day, except that he does not dry it. He then adds sulphuric acid which unites with the chalk and leaves the citric acid in solution, to be recovered by crystallization. It has long been thought by buyers that we might make citrate of lime and so save them

part of their work. Stated briefly, citrate of lime is made by exactly neutralizing lemon or lime juice with chalk, collecting the resulting precipitate and drying it. It is useful to remember that 7 parts of citric acid require 5 parts of chalk for neutralization.

Thirty or forty years ago, the late Sir John B. Lawes, an eminent chemist, tried this in Sicily, but the attempts were mostly failures, due, I believe, to the fact that the earlier experimenters, from motives of economy, tried to make citrate of lime with cold juice. They thought that if they could work with cold juice they would save fuel. The citrate of lime that was produced was slimy, very difficult to dry, and, once dried, very difficult to make wet again. The manufacturer found that he could not wet it; and you can quite understand that, as it gave him much trouble, he did not want it. Then they tried precipitating citrate of lime from hot juice. Prepared in this way, it subsides at once and becomes granular. You noticed this morning that the citrate of lime subsided immediately the stirring was stopped. When you begin to make it in this island, some one is sure to advise you to simplify the process and use the juice cold; don't do it, it has always failed. You are in the habit of distilling your juice, so you can run the juice straight from the still into a tank containing 200 or 300 gallons, and it should keep sufficiently hot, without the assistance of a steam coil, to make satisfactory citrate. You can easily make experiments. I cannot, as I have no large still in my laboratory. If this method of working proves satisfactory on a large scale, you can put up your plant without the addition of an expensive steam boiler. After that the process is very simple; the citrate subsides at once, and a few minutes later the greater part of the water can be drained away. You allow the citrate to subside, and then, having drained off the hot refuse, you can wash the citrate with hot water.

In the early experiments I made, I tried drying the citrate without washing. On inquiry I found that the manufacturers objected strongly to this, as the gums, etc., that remained turned a dark colour when the sulphuric acid was applied, which spoiled the citric acid. They all told me that unwashed citrates were things they would not handle. Unfortunately, what we made to-day was not properly washed. I believe that water should be turned on to the citrate before putting it into filters, and it should be washed till the washings are almost colourless. To test dried citrate, mix about 1 oz. of it with $\frac{1}{2}$ pint of hot water; if the water turns a dirty brown, the manufacturer would condemn it; if a pale lemon colour, he would regard it as satisfactory.

If you add too little chalk to your lime juice, you lose some acid. If you add too much, it gives the manufacturer trouble by wasting his sulphuric acid. The buyers of citrate of lime (four or five in England and two in the United States) have determined to penalize anything containing over 2 per cent. of chalk. If the citrate effervesces when lime juice is poured on to it, there is too much chalk.

These are the chief points to be observed. Citrate must be easily mixed with water, it must be free from chalk, and it must be colourless.

Now the question arises: Will it pay? Six months ago, both citrate of lime and concentrated juice were being sold at the same price, that is, both were sold merely on a citric acid basis: sometimes citrate commands a slightly higher price, but not one greatly higher. The question is: Is this state of things going to continue? You will have to buy your chalk, but the price is not great. When the manufacturer contracts to buy citrate, he wants stuff of a uniform quality. I take it that the reason why the price is the same as for concentrated lime juice is that really uniform, dependable citrate is not a certain article of commerce, and I believe that when we ship good citrate the price will improve.

If I were the owner of a lime estate, I would not at present change my plant, but I would keep myself well posted in citrate of lime so that I could change the works when necessary; and that, I take it, is the position to assume in Dominica.

For those who have no boiling house and who have to put up a plant, the matter is a very different one. It is difficult to decide what is best. For concentrating juice, the cost of appliances and working are already known; but for citrate of lime we are without experience, though the plant need not be expensive, especially if a still is used for heating the juice. The cost of importing chalk, difference in freight, etc., must be calculated, and these are in the nature of unknown quantities. The cost of producing citrate is not likely to be less than the cost of concentrating, but you are now in possession of sufficient information to enable you to discuss a change of method, should citrate at any time command a relatively higher price than concentrated juice.

In Sicily, lime juice is concentrated to 64 oz. per gallon; in Dominica to 120 oz. or so. In the latter case the destruction of acid is pretty considerable. I have been asked whether it is not better to lose, say, 5 per cent. of the acid and to save freight. It seems to me that the freight, duty, etc., form a very small proportion of the expense, and, speaking generally, I think it is desirable to stop concentrating as soon as the destruction of citric acid becomes appreciable. Juice of fine quality can be concentrated with safety to a higher degree than inferior juice; 96 oz. per gallon for low-grade juice, and up to, say, 120 oz. for high-grade juice, is sufficient concentration. I found manufacturers did not care for higher concentration. They also complained that some of our juice contained a quantity of iron: this interfered with the manufacture of citric acid. And then the juice was full of impurities. One must remember that this was the buyers' statement; but I have seen juice myself that could by no means be described as free from impurities. Something might be done to improve the standard of our juice by taking greater care in the manufacturing.

Then, another thing was pointed out to me. Practically the whole of the Sicilian crop is contracted for in the months from January to April. Our juice comes into the market at

a dead period to satisfy no immediate need. The manufacturers do not want it as they have enough, having made their contracts, and only buy ours because it is cheap. West Indian shippers might get much better prices if only they would make contracts.

Then there is the question of quantities. Contracts would be given for 25 hogsheads. At present the juice comes into the market in small lots and the buyers think it belongs only to peasant growers. Probably a little pushing and noticing of crops in trade journals might help a good deal. It seems to me that we are selling our juice in the worst market.

In writing on the subject, I mentioned that good coral might be burnt for lime, but I would not recommend that the whole of the process be completed with slaked lime. When that is done impurities are precipitated. Use, say, nine-tenths good building lime and finish the process with chalk. Lime to be suitable must be free from magnesia, iron, and earthy matter. There is very little magnesia in coral, and fresh coral from the sea is quite suitable: but old coral from the cliffs contains too much earth.

In the course of an interesting discussion that took place on the conclusion of Dr. Watts' address, the following points were elicited:—

In making citrate, the juice requires less boiling: the destruction of acid would be much less than by concentrating. In the latter case 7 or 8 per cent. at least is lost, while in the former only 2 or 3 per cent. is lost by washing with water. Any good drier, such as the one at the Botanic Station will do to dry it, but a much higher temperature will be necessary than for cacao, up to, perhaps, 250° F.

The first shipment of citrate of lime on a commercial scale was recently made from Dominica. In regard to this, Mr. J. Jones, Curator of the Botanic Station, forwarded for publication in the *Agricultural News* (Vol. V, p. 324) the following note:—

'Citrate of lime is now being shipped from Dominica on a commercial scale for the first time. The question of making citrate of lime instead of concentrating the lime juice, has exercised the minds of several planters in Dominica for a long time. As far back as 1902, the Hon. Dr. F. Watts gave a demonstration of the process of making citrate of lime before an assembly of planters at the Bath estate works. Dr. Watts also wrote a paper on the subject, which was published in the *West Indian Bulletin*, Vol. II, p. 308. The matter was also discussed before the local Agricultural Society.

'It is only during the present year that the matter has been actively taken up, and the first shipment made. The reports on this product have been uniformly favourable, the citrate of lime being quite crystalline, and containing 69 per cent. of citric acid. It was stated to be equal to the best Sicilian citrate.

'To make citrate of lime demands greater skill than the concentration of lime juice, and the expense is probably greater. Chalk has to be imported, and driers have to be erected, while the consumption of fuel in drying the citrate is very considerable. On the other hand, the planter who makes citrate produces a superior product which commands a higher price than concentrated lime juice; also the great loss of citric acid that is known to occur when boiling down lime juice, is prevented.

'It is found that evaporators built on the principle of the cacao drier at the Botanic Station are suitable for drying citrate. Particulars of this drier were given in the *West Indian Bulletin*, Vol. II, p. 173.

'Now that a successful start has been made, it is likely that Dominica will follow the example of Sicily, and in the course of a few years it may be that all the lime juice intended for citric acid makers may leave the island in the form of citrate of lime.'

The Treasury returns show that 598 cwt. of citrate of lime had been shipped from Dominica up to November 30 last.

It may be added that the manager of the Bath estate, Dominica, announces that the estate is prepared to purchase raw lime juice, for manufacture into citrate of lime, in any quantity on a basis of London prices for concentrated juice, less the cost of manufacture and other expenses.

It is also satisfactory to note that citrate of lime has now become an article of export from Montserrat.

In reference to the Sicilian trade in citrate of lime, it may be mentioned that the output of this product has been gradually increasing in recent years. It is exported chiefly from Palermo and Messina; the combined output of these two ports, which was 1,530 tons in 1900, amounted to 3,649 tons in 1904. To the latter figure must be added 117 tons from Syracuse, which is now also exporting citrate of lime.

KOLA IN WEST AFRICA.

The following information is extracted from a paper by L. Bernegau in the *Tropenpflanzer* (July 1904) entitled 'Study of the Kola Nut in Yorubaland':—

Lagos is the greatest market for fresh kola nuts on the West Coast of Africa. In 1902-3 the imports of kola nuts were valued at £35,968, and the exports at £1,127. In Ashanti and Yoruba, the kola tree gives two crops of nuts : a large one from September to January, and a small one from May to August. At the kola plantation at Agege, I saw in January on one part of a tree ripe fruits and flowers on another part.

Kola nuts reach Lagos almost exclusively from Ashanti and are shipped fresh from the ports Accra, Cape Coast Castle, and Saltpond. They belong to the species *Cola vera*, and are carried on deck tied up in sacking in large baskets, accompanied by the black kola traders. The baskets weigh about 1,500 lb. to 2,000 lb. I found one kola dealer with seven such baskets, i.e., nearly 7 tons of fresh kola nuts, chiefly nuts of red colour. In packing, the nuts are covered with two or three layers of the fresh juicy leaves of *Thaumatococcus Danielli*, or of other large-leaved plants. When the basket is full, the sacking is thoroughly secured by many ties of rope.

In Lagos, the kola nuts for export are unpacked and tied up in smaller baskets which are carried on donkey-back by Haussa merchants into the countries of the Soudan, especially into the great kingdom of Sokoto to Kano. From Kano. Tripoli merchants, Arabs, bring Kola nuts via Mursuk as far as Tripoli.

The Ashanti kola nut and the Mandingo kola nut (from the inner regions of Sierra Leone and Liberia) are the two kinds most favoured by the kola chewers of the Soudan. On an average, about £37,000 worth of fresh kola nuts are sent from Sierra Leone via Gambia to this region.

I examined a superior kind of kola fruit shown me by Mr. Rufus Wright, the proprietor of the large kola plantation at Agege, a black man, of the intelligent Ekba race. (The price of such superior kinds as the Laboshi kola is from 1*s*. 6*d*. to 1*s*. 9*d*. per 100 for red nuts.) The kola fruits formed a whorl on the stalk, as in all varieties of *Cola vera* or *Cola acuminata* which I have seen ; large, oval follicles, not smooth but corrugated on the exterior ; bright green colour ; the seed-vessel is about $\frac{2}{5}$ inch thick. Its inside is pure white. The white side when touched with the finger forms sticky threads. It turns yellow in the air after a few minutes, and brown in a day or two. On opening a fruit, the nuts are seen to be covered with a snow-white pulp, which turns yellow in the air. Six nuts are on one side and seven on the other. In other kola fruits there were only six seeds.

The smell of the pulp reminds one of the scent of certain apples. Its taste is a sweetish sour. When this pulp is

removed with a horn blade or a piece of ivory—steel knives should not be used—a thin skin is met with. On removing this skin, we reach the kola seeds or nuts. In the kola fruits of this variety there were differently coloured seeds, dark cherry-red, pink, pale-pink, flesh-coloured, and white, in the same fruit. The shape and size also varied. The deeper the colour the larger were the nuts. The white nuts formed about 1 per cent. of the whole. The Agege kola nuts, red and white, have two cotyledons. When cut, they turn brown in the air.

The Agege kola, when chewed, tasted bitter but not astringent. In twenty-five minutes the bitter taste quite disappears. Chewing this nut affects the salivary glands and relieves thirst. It produces a greater refreshing effect than can be obtained by drinking tea or coffee. Water, even if bad, drunk after chewing kola, tastes unusually refreshing. These qualities render it invaluable in traversing the deserts of the Soudan, where water is scarce and bad.

I visited the Agege plantation in company with the proprietor, Mr. Rufus Wright, and the German Consul, Mr. Gloye. It lies about 4 miles from the railway station at Agege, on the line from Lagos to Ibadan.

The plantation contained 2,000 kola trees, half being *Cola vera* and half *Cola acuminata*. There were also some fine old trees of *Cola acuminata*, which were probably planted in the then virgin forest, near native huts, thirty years or so ago. The plantation also included 60,000 coffee and 40,000 cacao trees. Cotton, yams, maize, sweet potatos, and pine-apples were grown between the trees. The shade plants were bananas, papaws, and cassava. We were informed that the coffee trees, having ceased to pay for the cost of gathering and preparing, were being removed, and kola was being set out instead, since the income from the kola had been beyond what had been anticipated. In 1903, a seven-year-old kola tree yielded a return of £2 10*s*., while a seven-year-old cacao tree, which cost more for cultivation, only brought in 1*s*.

Mr. Wright had had it suggested to him eight years ago in London to plant kola. He was now highly satisfied that he had done so and not followed his original purpose, which was to plant coffee and cacao only.

The proprietor acted as his own manager and visited his estate from time to time from Lagos. There was a native overseer on the plantation, and labourers were taken on as required. Hence the expenditure was small.

Nuts for planting were left three days in the sun, with the pulp on, before sowing. The nuts were put 1 foot apart in special seed-beds 2 or 3 inches deep. The seed-beds were made of black humus mixed with red loam and kept quite wet. They were watered every morning and evening and were shaded by palm-leaf roofs in the middle of the day. The seeds take about four weeks to germinate. After three or four months, when the rainy season began, the kola seedlings were taken from the seed-bed, with all the earth on their roots, and planted in their permanent positions. Or the seeds may be

sown separately in special plant-baskets, in which they can be conveyed more readily. Kola trees must be planted no less than 30 feet apart. Those trees which were nearest the river grew the best. At an elevation of more than 1,300 feet high the kola tree does not thrive.

The following additional information is taken from an article in *L'Agriculture Pratique des Pays Chauds*, by M. Jean Vuillet, Director of the Department of Agriculture for the Upper Senegal and Niger :—

1. *Cola vera*, K. Schumann. This attains 30 feet in height, and is planted by the natives around their villages in the forest regions of French Guinea, Sierra Leone, Liberia, Ivory Coast, and Gold Coast. Its seeds have two segments. This species is distinguished from the following one by the anthers not spreading and the stigmas uniting closely with the ovary.

2. *Cola acuminata*, K. Schumann. A tall tree, native of the forests of Cameroon, Gaboon, and Lower Congo. Its seeds are divided into four, five, or six segments. The kola tree of Dahomey must be connected with this species. At the exhibition of 1900, the Administrator, M. Jean Fonssagrives, wrote in the notice published by Dahomey : 'Dahomey kola is readily recognizable by each seed being divided into four or five parts. It is gathered mostly from Abomey-Calavi and the neighbourhood in September or October. The largest seeds are of a pink colour, the smallest a deep red ; some are even white.'

According to Dr. Bernegau, kola from Cameroon, when boiled for half an hour in water, forms shiny and silky filaments of gummy matter ; this is not the case with Liberian kola.

Professor K. Schumann, of the Berlin Botanic Garden, has given names to two other species of kola from Cameroon, whose seeds are utilized by the natives, together with those of *Cola acuminata*. These are *Cola lepidota*, with trifoliate leaves, and *Cola anomala*, with three leaves in a whorl.

Having lived for five years in French Soudan and visited the principal posts, we have noticed in the markets where kola always occupies an important place, three commercial kinds of this product, which seem to correspond to distinct botanical varieties: (1) Large nuts, of light yellowish-white colour, in comparison but slightly bitter, typical examples of which were seen at the market of Bobo-Dioulasso ; (2) usually middle-sized nuts, variable in size, yellowish-white or more or less deep-red, very bitter ; commonest in the markets of the districts of Sikasso, Bamako, and Ségou : (3) small red nuts, very bitter.

In crossing Binger, two kinds of kola were seen in the market of Kong : white kola from Anno, and red kola from Ashanti. There are two varieties of white kola from Anno : one is a pale yellowish-white like the kola of Sakhara from Worodouzou, but smaller : the other is of the same size, but is of a very pale pink, the colour being so faint that it is not called red kola by the natives. It is sold along with the white at the same price, which would not be the case if it were

darker in colour, for red kola is always dearer than white kola of the same size.

Anno kola tastes much less strongly than red kola, but it, too, produces a red dye which is used by the natives as well as that from the red kola. As a dye, the white kola from Anno is equal to the red kola from Ashanti. The former is picked in February, June, and October. The seeds picked in February soon spoil: those picked in June and October keep longer. It cannot, however, be carried on long journeys, for, with the best care, it can only be kept at most seven or eight weeks.

CULTIVATION.

The best species for cultivation is *Cola vera*, K. Schumann. As we have said already, this species is cultivated by the blacks around their villages, in the forest zone of French Guinea, Liberia, the Ivory Coast, and the Gold Coast.

Lieutenant Woelffel, in the report of his expedition, gives a very interesting description of the way the blacks practise this cultivation in the basin of the Upper Cavally:—

'The kola tree in order to grow well and produce good crops, requires shade, moisture, heat, and a soil rich in humus. The natives plant it preferably around their villages and along the sides of the paths, since they can watch these places. They are continually putting in new plants. In different districts the plantations belong to individuals or are the common property of the village. In the latter case, the customs which rule are curious. No one has the right to remove a branch from a tree or to take the seeds under pain of death. At the proper time the fruit is gathered and carefully counted. Then a general distribution is made, following certain rules: the number of kola seeds allotted varies with the age and social position of each person, but everybody, even the miserable captive, receives some.'

In general the kola cannot be cultivated in West Africa more than 9° from the equator. Further away the length of the dry season and the variations of temperature, which may descend occasionally below 50° F. at 10° N. latitude, would injure the growth.

M. Ch. Rivière has shown, in the experimental garden at Algiers, that this tree cannot support a temperature so low as 53° F., in a hot-house. With an insular climate the tree can succeed throughout the tropical zone.

The kola tree has a very deep tap-root. It will not succeed in a shallow soil, if the tap-root encounters water or rock. It does not thrive in places which may be flooded or where water stands in the soil during the rainy season. Transplantation being difficult, the seed should be sown in the centre of a spot where the soil has been dug up and manured for 3 feet deep and wide. The seed may also be sown in a shady nursery and transplanted with a large ball of earth round the roots after a few months, before the tap-root has grown long. They should be planted in the centre of spots prepared as above.

The kola tree requires moderate shading. This can be easily obtained by planting with it *Acacia Lebbek* and bananas in this order: the kola trees 30 feet apart every way, the acacias 60 feet apart, so that there is one acacia to every four kola trees; the bananas are put about 5 feet from each kola tree, one on each of four sides. Careful cutting out of some banana stems is required whenever the young kola plant is not getting sufficient light. The bananas are removed completely as soon as the shade of *Acacia Lebbek*, which grows rapidly, is sufficient. They serve to provide food for the labourers.

The kola tree needs little care. It is useful to dig around the young tree at the beginning and the end of the rainy season, and to apply then any available manure. During the early years, at least, a weeding of the plantation should take place between the two spadings. The tree begins to bear at five to six years, but a remunerative crop should not be expected before the tenth year. After this it produces many thousand nuts every year. It may also be propagated by cuttings and by marcottage.

More recent information in regard to kola was contained in the *Kew Bulletin* (No. 4, 1906). This article deals especially with Labogie kola :—

A general account of the kola nut has been already given in the *Kew Bulletin* for 1890, pp. 253-60. In an article by Count Zech on the Kola of West Africa (*Mitth. a. d. Deutsch. Schutzgebieten*, XIV, p. 12, 1901) reference is made to the 'Laboshi' kola of West Africa, which is stated by him to be more prized by the kola experts and traders of the Soudan than the Ashanti kola. The Count mentions especially nine localities as providing this superior kola, viz., Laboshi, Fashi, Yakudi, Gbaki, Patchiko, Kimbokun, Bete, Bitagi, and Koda.

In January 1904, specimens reached Kew from Mr. W. R. Elliott, Forestry Officer, Northern Nigeria, of the kola found by him growing in the Labogie district of the province of Nupe in Northern Nigeria. The letter accompanying the botanical specimens states that 'this particular variety of kola nut is in great demand throughout the whole of Northern Africa, and it fetches locally almost double the price of the kind with four or five cotyledons.' The letter continues: 'The kola plantations at Lobogie and other places in the district are situated in sheltered valleys at an elevation of from 450 to 550 feet above the sea. The soil is a deep, black, sandy loam, and is kept in a continuous state of moisture by the streams that are found in each valley. Very little care is taken of the trees, and they are found growing with the oil palm (*Elaeis guineensis*). The rainfall of the district is probably between 40 and 50 inches, but not a drop of rain falls from December to April.'

On examination, the specimens forwarded by Mr. Elliott were found to belong to the genuine *Cola acuminata*, Schott and Endl., (not of K. Schum.). This species is identical with the kola of Sierra Leone and Ashanti, although the seeds received from Labogie are rather below the average size of the Sierra Leone article.

The source of the 'Laboshi' or Lobogie kola was not previously known, and its determination was only possible after a thorough revision, by Dr. O. Stapf, of the group of species to which *Cola acuminata* belongs.

SYNONYMY OF COLA ACUMINATA.

Some dubiety has arisen as to the authorship of the species *Cola acuminata.* The subjoined note, prepared by Dr. Stapf, which explains the circumstances that have led to the uncertainty, may be of use in preventing a recurrence of the confusion that has been a consequence of this dubiety.

'*Cola acuminata* was originally described as *Sterculia acuminata* by Palisot de Beauvois in *Flora d'Oware et de Benin*, I, (1805), p. 41, t. 24, from specimens collected in the old kingdom of Oware in Southern Nigeria. When in 1832, Schott and Endlicher established the genus *Cola* (*Meletemata Botanica*, p. 33), they transferred *Sterculia acuminata* to *Cola* as *C. acuminata*. This publication was evidently overlooked by R. Brown, who, in 1844, contributed a description of *Cola acuminata* to Bennett's *Plantae Javanicae Rariores* (p. 237). The contribution appeared there without an author's name and was therefore attributed to R. Brown by subsequent authors, as for instance in *Flora of Tropical Africa*, Vol. I, p. 220, *Kew Bulletin*, for 1890, p. 253, and as recently as 1900 by K. Schumann in his *Sterculiaceae Africanae*, p. 125. The correct reference, however, is given in the *Index Kewensis*.

'Another complication was introduced into the nomenclature of the group of species to which *Cola acuminata* belongs, by K. Schumann's assumption that the *Sterculia* of Palisot de Beauvois was not the source of the so-called "true Cola" of Sierra Leone, which he described accordingly as a new species under the name of *Cola vera* (in *Notizblatt* des Botanischen Gardens u. Museums zu Berlin, III, (1900), pp. 10–18).

'Palisot de Beauvois' figures, particularly that of the embryo which shows two large cotyledons, leave, however, no doubt that he meant what is known as "true Cola," so that *Cola vera*, K. Schum. has to be considered as a synonym of *Cola acuminata*, Schott and Endl.'

THE COLA INDUSTRY OF THE GOLD COAST.

Dr. Gruner, District Commissioner, Togoland, who visited the Gold Coast in August 1903, on behalf of the German Colonial Agricultural Committee, for the purpose of obtaining information regarding the cacao and kola industries in that colony, published an interesting report on his visit in *Der Tropenpflanzer*, August, September, October 1904. A précis of this report drawn up by Mr. W. H. Johnson, F.L.S., Director of Agriculture, Gold Coast, has just been issued by the Government of the Gold Coast Colony. The note dealing with kola is as follows:—

'The kola tree is very seldom planted, and the tending of those trees produced by natural agency is limited to the clearing away of bush and weeds; but every such tree has an owner, who claims this right in virtue of having effected the first clearing.

'Kola trees raised from seed commence to fruit when six or seven years old; produce is small at this period, but increases yearly until the tree is mature, when it will yield from forty to fifty fruits.

'Two crops are produced annually, in December and April, of which the former is the principal. Fruits which fall off the trees are not collected, as they spoil rapidly; those plucked from the trees are stored in the shade, as the hot sun turns them black. When the nuts are freshly gathered, some difficulty is experienced in skinning them, but if they are stored for a short time, the skin can be readily removed with the fingers. If the nuts harvested exceed the demand, the surplus is skinned and packed with the leaves of a particular plant (*Thaumatococcus Danielli*, Benth.) in broad baskets made of palm leaves, and stored.

'The Hausas, who are the principal consumers, convey salt to the kola districts and barter it for kola, 1 ℔. of salt valued at 6*d.* being exchanged for 100 kola nuts. The price of kola, in the districts where it is produced, fluctuates between 3*d.* and 1*s.* per 100 nuts, but in Accra the cost of transport raises it to 1*s.* 6*d.* per 100. Kola is principally exported by sea to Lagos; the value of the exports in 1900 and 1901 were £43,133 and £35,024, respectively, while the estimated annual value of the exports overland to the hinterland is £75,000.

'The principal kola markets in Akim are Insuaim, Essamang, Kwaben, Tumfa, and Kankan. In Kwaben or Tumfa it is possible to purchase from a single person ten loads containing 2,000 nuts each. Previously the kola produced in Ashanti was only purchased by Hausas and transported by them northward to the Hausa States, but the restoration of order in Ashanti and the completion of the railway to Kumasi have facilitated the transport of this crop to the coast.'

THE IMPROVEMENT OF THE SUGAR-CANE BY SELECTION AND HYBRIDIZATION.*

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The discovery that the sugar-cane produces fertile seed, from which can be raised seedlings possessing varied characteristics as well as increased richness of juice, has placed cane growers in a position to endeavour to improve their varieties, so as to place the cane in an equally favourable position with the beet.

The attacks of various diseases and the general fall in the price of sugar made it necessary for all cane-growing countries to establish local departments to inquire into the best means of combating these disasters. Owing to the great influence of soil and climatic conditions on the yield of sugar, highly improved methods of cultivation and the use of modern appliances in manufacture, received considerable attention, as being the most direct means of accomplishing a cheaper production. It was, however, found that a hardier race of plants, which would give a greater tonnage of canes to the acre, was the first requisite, the quality of the juice being taken up for improvement later.

Although most of the older varieties of canes were found to suffer from the ravages of insects and disease, and, in consequence, a considerable loss of sugar was experienced, yet no serious steps were taken to inquire into the methods of preventing this loss until, in some instances, total crops had been almost entirely destroyed. Then the minds of a few began to turn to methods of obtaining improved varieties of canes. It became absolutely necessary to produce canes which were more resistant to disease, and at the same time, if possible, varieties which would give a larger yield of sugar per acre. This increased yield of sugar could be obtained in three ways, the combination of all three being the goal aimed at. These were: (a) by an increased tonnage of canes per acre; (b) by an increased yield of saccharose in the juice, with a higher ratio of purity; (c) by a freedom from rotten canes.

The differences apparent in existing varieties made it obvious that it was possible to produce new and improved

* This paper was presented to the Conference on Genetics held in London in August 1906 under the auspices of the Royal Horticultural Society, and is reprinted from the official report on the Conference.—[Ed. *W.I.B.*]

types superior to those already under cultivation; but, like all plants propagated mainly by cuttings, it was extremely difficult to notice slight variations amongst individual canes. Striking examples of seminal and bud variations had been noticed and some of these had proved of value. The following four methods were those by which variations were utilized to improve the quality of the crops: (1) Selection amongst native varieties; (2) Introduction of foreign varieties; (3) Hybridization between native varieties: (4) Hybridization between native and introduced varieties.

The first two methods will be dealt with very briefly, as they were carefully described at the Hybridization Conference held in New York in 1902.[1] (See References, p. 373.)

SELECTION.

The chief variations to be looked for amongst existing races of cane may conveniently be classed under three heads: (a) Variations in habit and vigour of growth; (b) Bud variations; (c) Variations in sugar contents of individual canes.

(*a*) *Variations in habit and vigour of growth.*—Amongst a large area of canes of any single variety, there were always to be seen some canes distinguishable by greater size and vigour. Planters were advised to select and cultivate such canes, as their great vigour seemed to indicate a greater power of resisting attacks of disease. This method has been tested practically under scientific supervision in the West Indies, and it has been found that many of the canes thus selected were capable of producing larger yields of sugar. Investigation of the more vigorous canes showed that they frequently varied to a considerable extent from the main crop, and therefore it is quite probable that many of them, instead of being variations of the mother type, were really seedlings which had come up in the fields, and had become cultivated in the next crop. Some of these variations could not be accounted for in any other way, and it was this peculiar appearance of new varieties of canes that subsequently led to the discovery of canes growing from seed.

(*b*) *Bud Variations.*—Bud varieties or *sports* are not uncommon in the sugar-cane. In fact, in 1886, a communication was addressed from the Royal Gardens, Kew, to all the sugar-producing colonies to stimulate inquiry into the advisability of searching for and cultivating sports on a large scale, as it was probable that some of these varieties would prove hardier and give a greater amount of sugar than the original stock.

In the summary of the observations on bud varieties of the sugar-cane up to 1901, given in the *West Indian Bulletin*, Vol. II, pp. 216-23, instances of such variations were recorded from widely separated countries, viz., Mauritius, Louisiana, West Indies, and Queensland.

Since then, other bud varieties have been noticed in the West Indies, and quite recently, two interesting accounts of sports have come to hand from Madras and Queensland.

In Queensland, one of the seedling canes has produced a sport which gave an analysis of 19·72 per cent. saccharose, as against 19·03 per cent. saccharose of the parent cane, and 18·97 per cent. of the next best seedling. It would appear that sports generally arise from striped or ribbon canes, and usually keep true to a whole colour; but instances have recently occurred in Barbados in which a green cane has given rise to a green and white striped sport. Clark, Queensland, holds that 'yellow sports have a tendency to grow sweeter than the coloured canes of the kindred variety.' This is not borne out by the instance lately recorded from Madras, for a striped cane has been found to sport into red and white canes, and 'whereas the white cane gave on analysis very similar results to the parent cane, the red sports excelled all other canes in the station in purity of juice.'

In order to put the relative merits of the sport canes and the original stock to a strictly comparative test, they were planted at the Experiment Station, Dodds, Barbados, side by side, in the same field, with other experiment canes.

The following figures taken from the report of Messrs. d'Albuquerque and Bovell on the agricultural work carried on at Barbados, 1900-2, under the direction of the Imperial Department of Agriculture for the West Indies, show the results obtained. For comparison, the return of White Transparent grown in the same field is also given:—

TABLE I.

Cane.	Canes. Tons per acre.	Juice per acre in Imperial gallons.	Pounds of saccharose per gallon.	Quotient of purity.	Pounds of saccharose per acre.
Original Stock (ribbon) ...	21·80	2,696	2·310	93·03	6,228
Sport Cane (white)	27·27	3,555	2·270	91·64	8,070
White Transparent.. ...	23·93	3,063	2·001	86·59	6,129

The yield from the sport cane in the experiments exceeds the yield from the original stock cane by nearly 2,000 lb. of saccharose per acre. This superiority was due to the higher tonnage of the white canes, their juice being slightly less rich in saccharose, and slightly less pure than the ribbon stock. The juice of both original stock and sport was rich in saccharose, and the results, so far, warrant their continued experimental cultivation.[2]

During the season 1903-5, this sport maintained its superiority over White Transparent, as may be seen from the following table which gives the mean results for these two varieties obtained from experimental plots on black-soil estates, together with the results of a Ribbon Cane, and of a Red Sport

cane. This latter, as can be seen from the table, has not proved satisfactory, but during the last growing season has been very vigorous and should give much better results:

TABLE II.

Cane.	Canes. Tons per acre.	Juice per acre in Imperial gallons.	Pounds of saccharose per gallon.	Quotient of purity.	Pounds of saccharose per acre.	Per cent. by No. of rotten canes.
White Sport* ...	26·06	3,407	1·954	84·45	6,645	1·55
White Transparent*	22·83	2,760	2·123	90·45	5,864	2·35
Ribbon Cane† ...	21·78	...	2·070	...	5,735	...
Red Sport†	19·23	...	2·051	...	5,131	...

Without doubt, these bud varieties deserve much more attention than is given to them, both on account of their economic importance, and also because the study of their variations may yield results of scientific and, probably, practical value. As to the cause of the real nature of these bud varieties very little is known at present. It has been suggested that these striped or ribbon canes are the results of cross-fertilization and that, therefore, the sports are to be considered as cases of dissociation and then segregation of hybrid characters, or of *atavism*.

It is supposed that unfavourable influences, either external or internal, temporarily encumber the growth of the young buds and predispose them to reversions. But, if sports are of an atavistic nature and are favoured by influences that impede normal growth, how is it that they, almost without exception, give such excellent results when cultivated, being hardier and richer than the original stock from which they arose?

(*c*) *Variations in sugar contents of individual canes.*—Bearing in mind the classical experimental work, with which the name of de Vilmorin is associated, in selection of the sugar beet, by which, through the aid of science, the sugar content has been raised from 10 to 18 per cent., workers with sugar-cane were led to commence investigations with regard to the chances of obtaining canes of higher saccharine content. The occurrence of a wide range of variation in the percentage of saccharose in the juice of canes of the same age and variety was soon noticed, and the fact that the sugar-cane was propagated by cuttings

* These results have been taken from Pamphlet No. 40 of the Imperial Department of Agriculture for the West Indies.

† These results have been obtained through the courtesy of Mr. J. R. Bovell, Agricultural Superintendent, Barbados.

naturally suggested that any improvement inherent in the plant could be developed more rapidly than if it had to be grown from seeds. Investigations in chemical selection have been carried out in the West Indies, but the results, so far obtained, are not at all conclusive.

d'Albuquerque, Barbados, at the last West Indian Agricultural Conference, 1905, stated that it would appear 'that, with a given variety, the richness or poorness of the seed-cane (i.e., cane used for planting) does not affect the quality of the juice of the resulting crop.' Harrison, British Guiana, concludes that the 'relative richness of seedlings is qualitatively, if not quantitatively, constant.' Watts, Antigua, however, states that 'some difference is induced by the process of selection, and, while this method of work is not likely to be followed by practical planters as a means of improving their canes, yet the fact is interesting from its scientific aspect as indicating that plants propagated by cuttings are subject to slight alterations.[3]'.

In Queensland it has been stated that improvement from single-stalk selection is not as great as would be expected, while in Java the evidence seems to point to the fact that selection amongst 'cane-clumps' is likely to give better results than selection among individual canes.

The following is the summary of the results of chemical selection investigations by Kobus in Java up to 1902, and has been abstracted from the *Journal of the Royal Horticultural Society*, 1903 (Vol. XXVIII, p. 298):—

'1. The amount of sugar in the individual haulms of one sugar plant was apt to vary greatly.'

'2. The variability of the amount of sugar in the different varieties was greatest in thick-stemmed varieties that had long been in cultivation, and least in young ones more recently selected from seed.'

'3. The amount of sugar in the cane varied directly with the weight of the same.'

'4. Heavy plants gave rise to heavy offspring.'

'5. The descendants of plants rich in sugar were richer in sugar and heavier than unselected plants.'

'6. Simple selection of cuttings of heavy plants did not lead to the production of forms markedly rich in sugar, though the resulting plants were in general richer in sugar. Indeed, heavy plants poor in sugar seemed to have a worse effect on the amount of sugar in the progeny than did light plants poor in sugar.'

'7. Extreme care had to be exercised in the selection of the ground on which the experiments were made; for, even in apparently uniform soil, great differences were apt to appear in the individual plants merely in consequence of local variations in the soil.'

'8. Increased vigour as reflected in larger yield of sugar was accompanied by greater immunity from "sereh" disease.'

This report is valuable as it confirms some results obtained elsewhere and at the same time presents many facts of great importance to those interested in raising seedling canes.

INTRODUCTION OF FOREIGN VARIETIES FOR FIELD CROPS.

The introduction and trial of standard varieties of sugar-cane from other countries is of considerable interest to planters, as probably this was the principal means by which the sugar-cane was distributed throughout the tropics.

Evidence, on the whole, seems to point to India and Polynesia as the original home of the sugar-cane, but it is now cultivated in various localities on both sides of the Equator ranging from the south of Spain, 37° north, to New Zealand, 37° south.

Of the older varieties of cane there appear to have been three or four which were extensively cultivated. In those countries where these are still free from disease, very few others have, as yet, taken their place; but where their cultivation has become impossible on account of the ravages of disease, others have been introduced to take their place.

In the West Indies, the Bourbon and Otaheite canes have almost entirely been replaced by other improved and hardier varieties. In Java, the introduction of the East Indian cane Chunnee was rendered necessary owing to the home cane being very liable to the 'sereh' disease.

Within the range of cultivation of the sugar-cane there are yet many countries where it might be largely grown if only the prevailing low prices should improve.

With the introduction of imported varieties it should be realized that there is always a danger of introducing new diseases and pests. It is important, therefore, that all imported plants be carefully fumigated and disinfected before being allowed to enter any country. Throughout the West Indies, laws of fumigation and disinfection of all imported cane cuttings are generally enforced, and, now that seedling canes are beginning to play such an important part in the improvement of the sugar-cane, and their introduction into new lands is becoming universal, it cannot be too strongly urged that all cane-growing countries should adopt means to prevent the introduction of new pests and diseases.

HYBRIDIZATION.

Having briefly reviewed the methods of selection, and the introduction of foreign varieties, it is now proposed to deal with the question of the improvement of the sugar-cane by hybridization. Although, perhaps, the contents of this paper may not appear to be in line with other papers read at this Conference, yet they may prove of value to our tropical possessions in showing what efforts are being made by cane growers in the colonies and elsewhere, to compete with the beet sugar production of European countries.

Bourbon. White Transparent.

390 6.06 Weller & Graham, L[td], Lithos. London

In Europe and America, much of the progress of agriculture during the last fifty years has been due to the continual improvement of the cultivated varieties of plants and to the production of new varieties.

In the tropics, such work, until lately, has been almost entirely neglected, and therefore a record of practically the first work in this direction should be interesting. Although such work has been possible for eighteen years, it is only within the last decade that systematic attempts have been made to raise seedling sugar-canes on a large scale. The remainder of this paper can therefore be divided into two parts, the first dealing with the different methods of producing hybrid canes that have been adopted by those working for this improvement, together with some of the results obtained, and the second part treating with the individual advances made by some of the more important cane-growing countries.

HISTORICAL.

The sugar-cane belongs to the *Andropogoneae*, a family of the true grasses (*Gramineae*). It has a solid stem, which often attains a height of nearly 20 feet, and contains the sweet juice from which the sugar is extracted. It is now generally conceded that all cultivated varieties of canes belong to one species, *Saccharum officinarum*, L., but there are reasons for believing in the existence of at least three other species. None of these, however, are regarded as of economic importance.

It would appear that sugar-canes, probably produced from seed, were observed at Barbados in 1848 and 1850, and the question respecting the possibility of growing seedling canes in the West Indies was raised at various times between 1859 and 1888. In the latter year, Harrison and Bovell from Barbados communicated to Kew that they had sixty cane plants under cultivation and that they were almost satisfied that they were seedlings.[4] This eventually proved to be so, and from that time systematic attempts to raise new varieties of seedling canes in Barbados, British Guiana, and elsewhere in the West Indies have been undertaken with highly satisfactory results.

A similar announcement as to the possibility of raising seedling sugar-canes was made by Soltwedel in Java in 1887.

Previous to 1887 or 1888 it was generally believed that the sugar-cane, in common with the banana and other tropical plants, had lost its power of producing fertile seed, and that all recorded observations of new canes up to this time were bud varieties or sports. However, since the establishment of the fact that the cane does produce fertile seed, the improvement of the sugar-cane by hybridization has made wonderful strides, and now experiments, conducted on scientific lines, are being carried out in Java, India, Hawaii, Queensland, Cuba, British West Indies, and British Guiana, etc., with the hope of raising canes less susceptible to disease and yielding a larger amount of sugar per acre.

DESCRIPTION OF FLOWER.

Before dealing with the different methods of obtaining hybrids, it may be advisable to give a description of the flower of the sugar-cane. The flower has often been described and figured, while good descriptions of the seed and its germination were given by Benecke in the Bulletin of the Middle Java Experiment Station, 1889, and also by Morris in the *Journal of the Linnean Society*, 1890.

The following description has been taken from notes made from the examination of many hundred flowers of different varieties during hybridization experiments this last year at Barbados, in 1905-6 :—

The inflorescence or *arrow* varies from 2 feet to 3 feet in length. It is repeatedly branched, each branch bearing laterally a number of spikelets. The numerous spikelets are one-flowered and hermaphrodite, and are generally arranged in pairs, one being sessile and the other stalked, at distances of a little more than $\frac{1}{8}$ inch on alternate sides of the slender, long branches. From the base of each spikelet, attached to the rachis, spring a large number of stiff, long, silky hairs, which give the inflorescence a glistening silky appearance in the sun.

The flower has the following formula :—

Glumes, 2; *Palea*, 1; *Lodicules*, 2; *Stamens*, 3; *Ovary*, single; *Style*, 1 (bifid).

The two glumes are nearly equal; oblong-lanceolate, acute; unawned; stiff; at first green, then purplish, the intensity of which varies in different varieties. The lower is two-nerved and measures 2·5 to 3·6 mm. long, by 0·7 to 0·9 mm. wide. The upper is distinctly one-ribbed, slightly keeled, and measures 2·8 to 3·8 mm. long, by 0·8 to 1·3 mm. wide. These measurements are the average of many investigations on different varieties, for, whereas the size of the glumes is generally constant in any given variety, between different varieties considerable variations have been observed.

The palea is solitary, thin, white, membranous, and is enclosed in the upper glume, than which it is slightly shorter. It is ovate-lanceolate, slightly obtuse, generally smooth, and apparently unveined.

The two lodicules are free, minute, truncate or 2-3 lobed, and vary in colour from white to yellowish green.

The stamens are three in number (during hybridization experiments at Barbados in 1905-6 three instances of four were found and noted), the anthers are linear-oblong, versatile, and vary in colour from yellow when young to a deep yellowish-red when mature.

Ovary smooth, unicarpellary, style one, bifid. The styles vary considerably even in the same variety, for in some instances a single style springs from the top of the ovary and soon becomes bifid; while, in others, there are two styles distinct throughout. The stigmatic plumes are always two in

number and are large, densely plumose, and dark reddish purple.

The fact that the anthers are versatile and the stigmatic plumes feathery would lead to the conclusion that the sugar-cane. like the majority of the grasses, is naturally wind pollinated; for when the versatile anthers burst, the pollen is much more easily scattered by the wind than would be the case if they were firmly fixed: it is also the more easily caught by the feathery stigmata. This is a point that is still under investigation and is one of considerable importance in the work of hybridization.

METHODS OF OBTAINING SEEDLINGS.

In some countries the earliest method adopted for obtaining seedling canes was by a collection of fertile seeds or casually produced seedlings from the fields.

A later step was the identity of the seedlings from the seed-bearing parent. This method was the one early adopted by Harrison and Jenman in British Guiana. The cane from which the arrow was taken was carefully recorded, and thence commenced a stock of new varieties of canes with the parentage known on one side only.

A further stage was the raising of seedlings from two varieties of canes by planting in adjoining rows varieties known to arrow at the same time. By this means there was a possibility that the pollen-bearing parent might be identified as well as the seed-bearing parent.

Thousands of seedlings have been raised by these methods, but, although the seed-bearing parent was known and registered, the pollen-bearing parent was still uncertain. In consequence, a large majority of the seedlings were found to be less valuable than the seed-bearing parent originally selected. In many cases, however, it was evident that the resulting seedling canes were true hybrids. These hybrids, when they possessed a vigorous habit and a high saccharine content. were carefully propagated and subjected to a rigorous system of selection.

The fixing of good varieties was rendered more easy, as plants raised from cuttings come true to the parent forms, and do not necessitate additional selection year after year. After these seedlings had been sufficiently investigated to warrant recommendation to the planters, they were gradually introduced into general cultivation, and have proved the means of overcoming to a considerable extent the ravages of disease, as many were hardier than their parent forms.

Through the uncertainty of the results of the above-mentioned methods of what may be called natural or chance hybridization, it was considered advisable to conduct hybridization under control, and by this means it was hoped to combine some of the desirable characters of both parents, and therefore produce pedigree canes, which could be recommended for general cultivation.

At the second West Indian Agricultural Conference of Barbados in 1900, d'Albuquerque, after discussing methods in

securing natural hybrids which, however, did not ensure against the risk of pollen from an unknown source, recommended an artificial method of securing cross-pollination, e.g., 'to bag each arrow under experiment some time before it is ripe, and when the arrows in the bags are ripe, to shake the contents of the bags of one variety into the bags covering the arrows of another, the latter bags being temporarily opened at the top to receive the pollen, and then closed up; every possible precaution being taken to prevent, during the transference, the access of pollen from any other source.'[5]

It was, however, pointed out that such a method did not entirely prevent self-pollination, and therefore it has been replaced by others in which the risk is not so great.

In 1894, it was found by Wakker in Java that the Cheribon cane did not bear fertile pollen while the pistil was normal, and therefore any seedlings raised from this cane would be the result of cross-fertilization. This was a great advance in the hybridization problem of the sugar-cane. Kobus, by planting other good varieties known to possess fertile pollen by the side of this Cheribon cane, obtained thousands of seedlings as the result of inter-crossing. Investigations in Java upon the raising of sugar-cane seedlings centred around this discovery, and, therefore, in 1902 a large number of the best seedlings canes at Barbados were examined by Lewton-Brain [6] in the laboratory of the Imperial Department of Agriculture for the West Indies to inquire into the proportions of fertile to infertile pollen in the anthers of different varieties. By this means it was possible to divide the West Indian varieties of canes into three classes: (1) in which the anthers show a large proportion of normal pollen; (2) in which the anthers show a very small proportion of normal pollen, (3) in which the anthers show a moderate proportion of normal pollen. If, therefore, an arrow of a cane producing much normal pollen is bagged with an arrow of a cane producing little fertile pollen, the risk of self-fertilization is reduced to a minimum, and if fertile seeds are produced by these canes, they will almost certainly be the result of hybridization.

The possibilities of the hybridization of the sugar-cane under control, by removing the stamens of one flower and the transference of pollen from another, were discussed by Boname, Mauritius, in 1899. It was thought, however, that this was almost impracticable on account of the large number of flowers on each panicle, and also their microscopic size. It was also pointed out that it was not known, with certainty, whether the flowers of the sugar-cane were autogamous or not, and, therefore, emasculation would have to take place while the flowers were very young. The emasculation of immature spikelets of the sugar-cane without injuring the very delicate ovary and stigmatic plumes was thought to be an operation of considerable difficulty, and, therefore, the raising of seedlings by hybridization under control was dismissed as being impossible. In 1900, d'Albuquerque stated that, to ensure that the seedling canes produced are the result of cross-fertilization between the parents selected 'would need the elimination of the

anthers before they were mature—a very difficult task in a plant, the parts of whose flowers are so small as in the sugar-cane;' but in 1904, Lewton-Brain, after consultation with d'Albuquerque and Bovell, performed experiments in artificial cross-pollination, in which the flowers of one variety were emasculated while still young, covered in a muslin bag, and then pollen from another variety was transferred to them by hand. This method of raising hybrids by artificial cross-pollination proved successful. Five stools of hybrid canes were raised in Barbados as the result of this work. It is reported that four pedigree hybrids have been raised in Queensland, and in Cuba about 600 are said to be now under investigation.

The operation of emasculating the flowers has to be performed under a dissecting microscope upon a platform 8 or 9 feet above the ground. Such an operation under field conditions with a strong wind blowing is attended with considerable difficulty. Even when accomplished, an unfavourable season with very hot dry winds or heavy rains is likely to destroy the chance of good results. That so much depends upon the season may be seen by the results from Cuba. Four years' work yielded but two hybrid seedlings, while the work of a single favourable season produced 600.

Having established the fact that hybrids of sugar-cane can be obtained by cross-pollination under control, it remains to discuss briefly the best methods of attacking the problem of raising disease-resistant varieties with a large sugar content.

OUTLINES FOR FUTURE WORK.

Formerly, with a nearly common standard of perfection, the attempts to procure an improved race of sugar-canes centred around breeding from the best varieties; but now, by carefully analysing the different characters of the different varieties under cultivation, it may be possible to breed methodically for definite objects.

The work on inheritance carried out by Mendel and communicated to the Brunn Society in 1865, and since so ably elucidated by Bateson, shows conclusively that the gametes are pure with respect to the characters they carry. Further, the work of Biffen with wheat breeding should serve as a model on which breeding of sugar-canes should be carried on. By following such methods, instead making a considerable number of crosses indiscriminately with the hope of obtaining some improvements, hybridization on definite lines should now be carried out.

The first thing to consider, therefore, is what desirable characters are required to be chosen. As it is necessary that the hybrids should be an improvement commercially, only those characteristics of the cane which appeal to the planter should be considered. The chief amongst these are:—

(1) Behaviour under extreme conditions of drought or excessive moisture.

(2) Maturity—whether early or late.

(3) Disease-resisting power.

(4) Milling qualities.

(5) Tonnage of canes per acre.

(6) Richness of juice in saccharose.

(7) Purity of juice.

It would be impossible at the outset to consider all these characters and, consequently, it would be advisable to work with those which are of greatest value economically.

The essential characters to be considered are resistance to drought, resistance to disease, a larger tonnage of cane per acre, richness of juice in saccharose, and, in some of the northernmost countries, early maturity. As a result of the previous work done in breeding sugar-canes, it is now obvious, that a class of canes has been produced that possess, to a large extent, qualities which enable them to resist certain classes of disease. Most of the newer seedlings possess a thicker cuticle than the older varieties and are, therefore, more or less immune from the attacks of insect pests, and possibly some physiological reaction within the plants enables them to withstand the attacks of certain fungoid diseases. More, however, requires to be done in this direction, for the root disease, for instance, is one which does a considerable amount of damage in the West Indies, Hawaii, and elsewhere. In Java, it is held that a larger yield of sugar depends upon the cane possessing an increased vigour, and also greatly upon immunity from disease, and therefore breeding for resistance to disease (the root disease in particular) is one of the first points to be aimed at.

The tonnage of cane per acre is specially a point of great importance. In 1902, Harrison reports that 'the results confirm those of previous experiments, that neither the addition of phosphoric acid, of potash, or of lime to the manures favourably affects the sugar contents of the juice of the canes. The effects of nitrogenous manurings appear to be somewhat to retard the maturation of the canes, and thus the juice of canes manured with them is as a rule not so rich in saccharose as is that of canes grown without manure. But this effect is far more than off-set by the larger yields of produce resulting from the application of nitrogenous manures, and to the fact that the increases produced by the nitrogen are principally due to the development of the stalks in length and in bulk, and not to abnormal increases in the amounts of tops and leaves or the production of new shoots to the stool.' Watts [7] and Cousins have shown that different manures influence greatly the yield of cane per acre without appreciably altering the saccharine richness of the juice. Moreover, Cousins, [8] Jamaica, holds that 'beyond a certain point—24 per cent. saccharose in the juice—any increase in richness involves a reduction in agricultural yield.' He also believes that 'the line of development of the sugar-cane as a cultivated plant, lies primarily in the direction of increased tonnage of cane, and secondarily, in that of greater purity of juice.'

As only a few of the varieties now under experiment possess over 20 per cent. saccharose in the juice, maximum

productiveness has not been obtained; but nevertheless, it would appear that disease resistance and a larger tonnage of cane per acre, both of which depend largely upon increased vigour of the cane, should receive first attention.

With the view of obtaining some clue to the more prominent characters of the different varieties in Barbados, several arrows or inflorescences were bagged separately before they were ripe to ensure self-fertilization, and many seedlings have been obtained. As the varieties chosen were hybrids, the records of this second generation should give on analysis results that will be of assistance in the subsequent hybridization work, for the splitting of the different characteristics has been carefully noted.

Many of the previous records of work on the raising of seedling canes show that some varieties possess striking dominant characters, which are transmitted to their offspring. Kobus,[9] in Java, states that 'in some cases the fecundating power of the pollen of the Chunnee variety is so strong that more than 95 per cent. of the hybrids resemble the male parent.' The hybrids in Barbados, as might be expected, also show that certain external characteristics resemble those of one of the parents.

In the experimental work carried on at Barbados on these lines, only those varieties that have stood the stringent tests on a large scale for a considerable time, under varying conditions of soils and climate, were chosen, as many of the newer seedlings show fluctuating variations when submitted to adverse conditions. Care in securing good parent varieties is of the greatest importance, because the number of varieties which may be kept under trial is limited. After having chosen the variety, it is essential that only the choicest individuals are taken for experimental purposes, for in Java, it has been found that the amount of sugar in a cane varies directly with the weight of the cane, and also, as a rule, heavy plants give rise to heavy offspring.

Once having obtained the desired type of seedling, it will be easy to multiply it to any extent without the necessity of fixing the type by further breeding, as the sugar-cane on a large scale is propagated by cuttings and not by seed.

CLASSIFICATION AND AN APPEAL FOR UNIFORMITY.

Having reviewed the method of obtaining seedlings and some of the problems for future work, it becomes necessary to discuss some of the results already obtained. Perhaps the best way is to describe the advances made by the various sugar-producing countries separately. Before doing this, however, it will be advisable to notice in passing the methods of naming and classifying the different varieties of canes.

Most of the older writers classified canes according to the countries of their origin; in many cases their true origin was unknown and, therefore, new names were provided. Subsequently, local names were assigned to the same variety, and shortly a confusing number of synonyms was established. In 1890, Harrison and Jenman[10] recorded that, in their collection

of the world's canes on the Experiment Stations in British Guiana, the *Bourbon* cane (one of the oldest varieties) was represented under six distinct names, and the *White Transparent* under four.

They therefore suggested that a system of classification should be universally devised, and finally concluded that the best and easiest method was to arrange them in groups according to their outward characters.

Five classes were formed :—

(1) Yellowish green or green, often blotched with red.
(2) White, vinous, or brown-tinged canes.
(3) Grey or pink-tinged canes.
(4) Ribbon or striped canes.
(5) Claret or purple canes.

Stubbs [11] in Louisiana, however, recognizes only three classes in distinction to the five of Harrison and Jenman, viz. :—

(1) White, yellow, or green canes.
(2) Striped canes.
(3) Solid colours other than in (1).

In comparing these two independent classifications and looking at the synonyms established, it is seen that differences occur, but they show fairly conclusively that the older cultivated varieties of sugar-cane were few in number, and presented only those differences which were due to changes of cultivation, climate, and environment.

Since the advent of seedling canes it has become customary to designate their origin by the initial letter of the name of country in which they were originally raised, with an affixed number, e.g., B. 147, (Barbados Number 147), D. 95, (Demerara Number 95), T. 24, (Trinidad Number 24), J. 30, (Jamaica Number 30), etc. Seeing, therefore, that the hybridization of the sugar-cane is now becoming general all over the tropics, it is essential that some scheme for naming and classification be devised, or else a greater confusion than ever will be the result. All workers, therefore, in the production of seedling canes should see that a letter and a number be affixed to the new seedlings before distribution, and a system of classification based on colour and other external appearances be adopted.

If such or any other system were uniformly adopted, it would be easy to compare the results of a given variety when grown under different conditions and in different parts of the world.

RESULTS ALREADY OBTAINED.

India.

Efforts to improve the sugar-cane in India have only recently been made. With the establishment of the Samalkota Experiment Sugar Station in Madras, the cultivation of the sugar-cane under Indian conditions is being carefully studied. Several varieties of canes have been introduced from other countries, and the shipments from Mauritius and Barbados have given good results, the yield of these varieties comparing very favourably with the home canes.

One of the imported Mauritius canes was a ribbon cane called Striped Mauritius, and Barber, in his report on the station for 1904-5, states that this cane has given rise to bud varieties, red and white sports being produced. These sports have been carefully grown and analysed, with the result that the red sports have proved better than any other canes that are grown at the station in respect to richness of juice.

In 1903-4, a number of canes arrowed at the station, and an effort was made to obtain cane seedlings, but without success. In the following year a number of boxes were planted with arrows from different kinds of canes. Two seedlings were obtained from the Mauritius canes, but they lived only for a short time.

Although previous to this time repeated mention of cane seed has been made in different parts of India, no record of the seed being fertile seems to have been reported.

Barber states that these experiments with cane arrows were directed mainly towards the investigation of whether the sugar-cane produced fertile seed in India. This has therefore been shown to be the case, but it is thought that the burning dry air of the Indian climate is unsuitable to the successful raising of seedling canes, and that the cultivation of sports appears to be much more practical than the raising of seedling canes. The raising of hybrid canes, however, would possibly be a means of combating many of the diseases that cause so much trouble to cultivators of sugar-cane in India.

Queensland.

The raising of cane seedlings has received some attention in Queensland, as reports to hand state that nine seedlings were obtained from arrows collected in 1889, and five from those collected in 1891. One of these earlier seedlings has given the white sport, referred to previously, which has proved to be the best of all the seedling varieties.

In 1900, a selection of West Indian seedling canes was imported, with the result that last year, at Wellington Point, some gave analyses which compared very favourably with the home seedlings, while the information gathered from the latest reports confirms the value of B. 208 (Barbados No. 208) as a cane for cultivation in Queensland.

In 1901, there were obtained by the Queensland Acclimatization Society 700 seedlings, of which 300 were approved plants, and, in 1903, 170 plants were selected out of 500.

In 1904, experiments in artificial cross-pollination were undertaken and four hybrids were obtained. These were the results of a cross between B. 208 as seed-bearing parent and Striped Singapore as pollen-bearing parent. This shows that hybridization is possible, and instructive results are expected to follow.

The following will show that seedlings are giving satisfactory results in Queensland: In 1903, only one cane gave over 19 per cent. possible obtainable cane sugar, whereas, in 1904, six exceeded this amount. How much this had to do with the

season cannot be stated definitely, but it seems to point to the fact that in Queensland, as elsewhere, seedling canes may gradually supplant the older varieties.

Grimley states that B. 208 on one estate gave a 'return of 69 tons 6 cwt. of cane per acre with 22·2 per cent. of sucrose, and Brix 23·09, or 21·45 per cent. of possible obtainable cane sugar, or over 14 tons to the acre. These results were obtained under irrigation, and the experiment plot was well manured. The average yield in Queensland per acre for the last seven years was 13·16 tons, so that B. 208 gave more sugar per acre than the average tons of canes per acre in Queensland.'[12]

Hawaii.

With the establishment of the Hawaiian Sugar Planters' Association, the propagation of new varieties of canes, which are resistant to disease and at the same time good sugar producers, was considered to be of paramount importance.

In the season 1904-5 no young canes were obtained from the home-grown seed, but large numbers of seedlings were obtained from seed introduced from Barbados, Jamaica, and Trinidad. In all, 279 seedling canes were obtained and planted out; ninety-three of these were cut up and replanted as cuttings, while the remainder were allowed to remain to flower, when it was hoped that a considerable quantity of fertile seed would be obtained.

Artificial cross-pollination experiments were conducted last season, but, so far, the results are not known to the authors of this paper.

The introduction of foreign varieties is largely practised, seedlings from Demerara, Barbados, and Queensland have been introduced, and it is stated that 'D. 117 holds the lead among the recently introduced varieties and is a promising cane worthy of trial under the diversified conditions of the island.' Among other very promising seedling canes are B. 147, B. 156, B. 208, D. 145, and Q. 1.

Louisiana.

Owing to the shortness of the growing season, which is limited to about eight months on account of frosts, the home canes in Louisiana rarely arrow. Seedlings from these home canes have not been obtained, and therefore planters have to rely upon imported varieties. Seedling canes from Demerara, Barbados, Jamaica, and Queensland have been imported, and submitted to trial at the Experiment Station. A large number were found to be unworthy of recommendation to the planters, others are still under experiment, and two of the Demerara seedlings, viz., D. 74 and D. 95, have surpassed all the home canes.

D. 74 is a tall, green, erect cane with long internodes, long and deep roots, ratoons (i.e., sprouts for second crop) well, and has a large sugar content. The individual canes are large and heavy.

D. No 74.

[illegible]

390 6 06

Weller & Graham Ltd, Lithos London.

D. 95 is a large, purple, erect cane with long internodes, long and deep roots, ratoons well, has a large sugar content, and large individual stalks.

Blouin reports that both these canes are very hardy, mature early, and that their erect habit renders them better able to withstand storms and makes them more easy to harvest.

During 1905, D. 74 arrowed in Louisiana, this being the first seedling that has flowered in that State.* From this it may be inferred that this cane is one which quickly matures. If it matures while the older varieties remain immature, and gives a high sugar content, it should prove to be a valuable cane to sugar planters in Louisiana. The planters fully appreciate the value of these varieties, as it is estimated that nearly four-fifths of them have introduced one or both of the Demerara seedlings into their cultivation, and, if these canes continue to flourish, nearly two-thirds of Louisiana's cane area will be planted with them in two or three years' time.

Mauritius.

A large number of varieties of canes are grown in Mauritius, amongst which are two sports of the Striped Tanna which have been submitted to extensive trial. The White Tanna is whitish and resembles the parent cane in many respects and is now held in favour. The Black Tanna, also a bud variety of the striped cane, presents many characters of the parent cane, but is not extensively grown.

Seedlings were successfully raised shortly after the discovery of fertile seed in Java and Barbados, a large number of which were distributed to estates. These seedlings gave such good results that managers frequently started seedling nurseries of their own, and much confusion in nomenclature followed.

The first seedlings grown were chosen haphazard, but eventually various systems were evolved, such as planting in alternate rows and bagging the arrows on the chance of getting fertile seeds.

It is also interesting to note that, as early as 1889, a method of what may be called natural hybridization, by which several hybrids have been obtained in the West Indies, was fully discussed by Boname,[13] but was thought to be impracticable on a field scale. It was suggested that the inflorescence be enclosed in muslin bags when quite young and then the inflorescence of another be introduced when its flowers were ready for pollination. No record can be found of this method being practised in Mauritius.

The raising of seedlings in Mauritius appears to have centred around the collection of the arrows from their best varieties. The Big Tanna, which is one of their most vigorous canes, has received considerable attention, and a large number of seedlings have been obtained from it. Although many of

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* Since this paper was written, it has been announced that seedling canes have been successfully raised for the first time in Louisiana (*Agricultural News*, Barbados, Vol. V, p. 307).

these seedlings have proved to be worthless and others have shown great fluctuations, yet a considerable number have been produced, some of which not only show a greater saccharine content than the other varieties, but also a greater resistance to disease and, consequently, give a larger yield of sugar per acre than most of the older varieties.

JAVA.

The raising and cultivation of seedling canes have been taken up to a considerable extent in Java, on account of their comparative freedom from disease. After the discovery of fertile seed of the sugar-cane in 1887, many of the larger planters cut the cane arrows, planted them, and raised large numbers of seedling plants. From these they selected such as had a high saccharine content and showed themselves able to resist disease for planting on a large scale, and then finally selected those which were best suited to their estates.

Owing, however, to the insufficiency of the trials before introduction into the general cultivation, much distress was incurred, and therefore planters began to look to the Experiment Stations for selected seedling canes.

In 1894, Wakker, the Director of the East Java Experiment Station, discovered that the Cheribon cane bore infertile pollen, while the ovary was normal. Bouricius crossed the Cheribon with the Fidji, and later Kobus crossed it with the Chunnee, one of the imported East Indian canes, for this showed a large proportion of fertile pollen. The two chosen varieties were planted alternately in rows in order to obtain natural cross-pollination. A very large number of seedlings was obtained by sowing seeds from the 'self-sterile' arrows of the Cheribon, many of which combine the high sugar content of the Cheribon with the disease-resisting power of other selected varieties.*

All the resulting seedlings are tested in the station for four years before being recommended for general cultivation. In this way a race of hardier canes has been established, and the sugar content has not been noticeably decreased, although one of the varieties used as a parent was rather low in percentage of saccharose.

The choice of the Chunnee variety as one of the standards to be used for crossing purposes has even been more valuable than the experimentalists dared at one time to hope, for all the seedlings at the Experiment Stations that are the decendants of the Chunnee are less subject to root disease, as well as to other maladies. They are, however, somewhat hard, which is an inconvenience for crushing purposes, but it is not thought that this property is undesirable, as it is counterbalanced by others that are useful.

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* In 1905, over 16,000 seedlings were raised at the East Java Experiment Station. Of these, the parentage of 7,170 was known on both sides, for they were produced by the above method, and that of 7,400 others was known on one side only.

Efforts are now being made to raise other races of plants, one—a more hardy race of seedlings—by crossing those seedlings already obtained with the immune variety Chunnee, and the other—a richer race of seedlings—by crossing seedling canes with the Cheribon, and also with other seedlings.

Although the results are not coming out exactly as anticipated, an examination of the following table will show that considerable improvement has been made.

The contents of the following table have been extracted from that given by Kobus[14] in 1905, embodying the experimental tests with the different varieties of seedling canes at the East Java Experiment Station. The figures given by Kobus have all been converted into English units so that they may be used for comparison with the results obtained in the West Indies. This table illustrates clearly how the yield of many seedling canes is much better than that of the standard variety—Cheribon :—

TABLE III.

No.	Soil.	Tons of cane per acre.	Per cent. pure sugar in cane.	Pounds of sugar per acre.
Cheribon	Light	37·9	11·79	9,928
146	,,	62·8	13·55	19,085
213	,,	62·9	13·34	19,250
247 B.	,,	70·1	11·54	20,394

By this it can be seen that many of the seedling varieties give an estimated yield of sugar per acre of about double that given by the old standard variety.

So far, no records have come to hand from Java to show that hand cross-pollination has been successful, but now that it has been shown to be possible in several different countries, there can be no reason why the raising of hybrid sugar-canes under control should not be as possible in Java as elsewhere.

CUBA.

Experiments have been conducted with the introduction of standard varieties and seedlings from Java, Queensland, and the British West Indies. After considerable testing, many of these are being introduced into the general cultivation. B. 208 has been giving excellent results both in percentage of saccharose and purity of juice.

Four years of careful hybridization resulted in but two seedlings, but during the last year (1905-6), owing to a favourable season, over 600 seedlings have been obtained by Atkins[15] at the Harvard Experiment Station, and nearly all of these are the result of hand cross-pollination. Emasculation was effected

during early morning when the anthers were full-grown but unexpanded, and pollination was continued for several days, the spikelets being kept under gauze cloth. It is moreover shown in his report, that great care must be taken with the germination of the seeds, much depending upon the soil used, on the depth to which they are set, and on the watering.

This report is, without doubt, a valuable one, as it shows conclusively, that with a favourable season, seedlings of the sugar-cane can be obtained in large quantities as the result of cross-pollination.

British West Indies and British Guiana.

Since the establishment of the fact in 1887 and 1888, by Soltwedel in Java and Harrison and Bovell in Barbados, that the sugar-cane at times does bear fertile seeds, systematic attempts have been continued in the West Indies and British Guiana towards the raising of improved races of seedling canes. All the different methods of selection, before referred to, have been adopted, with the result that thousands of seedlings have been raised, from which a few good ones have been chosen and recommended to planters for trial. It was thought, however, that it was essential to select both parents, and the various methods to ensure the crossing of the chosen varieties were given an extended trial. The method of planting in alternate rows varieties that had practically unisexual flowers, which has given such good results in Java, has been experimented with, but, owing to the success of Lewton-Brain in 1904 at Barbados in obtaining seedlings by hand cross-pollination, it is now held that artificial hybridization of the sugar-cane is practicable and ensures the best results in the shortest possible time.

Having briefly referred to the methods adopted for the raising of seedling canes in the West Indies, some of the results already obtained may be reviewed in order to show what improvement has been made. The 'Bourbon' cane was at one time the standard cane of the West Indies, but owing to fungoid diseases, its cultivation had to be given up, and other varieties substituted in its place. In Barbados the cultivation of the Bourbon cane has been entirely abandoned, and another variety, the White Transparent, has taken its place as the standard cane.

Barbados.—Thousands of seedlings are raised yearly in Barbados from the planting of the arrows from the better varieties, and these are submitted to rigorous selection on the tonnage of canes per acre and the chemical analysis of the juice. During the last five years in Barbados over 20,000 seedling canes have been raised and planted out, but less than 1 per cent. of these have stood the stringent tests of field and chemical selection applied to them. In the season 1904-5, over 7,000 plants were raised from seed, and out of these only ninety-five were considered worthy of further propagation. It may be urged that a large number of seedlings are in this way wasted every year, but it is held by Bovell that, owing to the limited extent of the experimental grounds, it is necessary to

limit the cultivation to seedlings that give an estimated yield of 30 tons of canes per acre and a saccharine content of over 18 per cent. This year, 1906, about 5,000 seedlings have been planted out, from which it is not expected to choose more than 100 for further propagation, and it is doubtful whether more than one of these will prove worthy of recommendation for planting on a large scale.

Work on these lines has been continuously pursued in Barbados since about 1888, and the following tables of results, extracted from the reports recently issued by d'Albuquerque and Bovell on the experiment work with sugar-cane, under the direction of the Imperial Department of Agriculture, show that many of these seedling canes give results vastly superior to the standard variety :—

TABLE IV.

MEAN RESULTS—BLACK SOILS—FOR SEASONS 1900-5.

Cane.	Canes. Tons per acre.	Per cent. of rotten canes.	Saccharose. Pounds per gallon.	Quotient of purity per cent.	Saccharose. Pounds per acre.	Muscovado yield. Tons.
B. 1,529 (1904-5) ...	28·92	1·54	2·406	92·18	8,477	3·03
B. 147 (1900-5) ...	28·35	3·77	1·912	86·88	7,006	2·50
B. 208 (1900-5) ...	24·72	4·93	2·250	90·70	6,863	2·45
White Transparent (1901-5)	25·22	5·99	2·038	89·70	6,453	2·30

TABLE V.

MEAN RESULTS—RED SOILS—FOR SEASONS 1900-5.

Cane.	Canes. Tons per acre.	Per cent. of rotten canes.	Saccharose. Pounds per gallon.	Quotient of purity per cent.	Saccharose. Pounds per acre.	Muscovado yield. Tons.
B. 1,529 (1904-5) ...	27·12	1·67	2·270	93·79	7,428	2·65
B. 208 (1900-5) ...	26·78	5·52	2·146	91·23	6,695	2·39
White Transparent (1901-5)	22·24	4·93	1·979	90·09	5,404	1·93

It will be seen by the above tables that B. 1,529 gave an average, in both red and black soils, of 2,024 lb. of sugar per acre more than White Transparent, while B. 208, a cane which has lately become extensively cultivated in different parts of the West Indies and elsewhere, gave a yield of 410 lb. in black soils and 1,291 lb. of sugar per acre in red soils more than the standard variety.

These tables have been prepared as they give the results of experiments over an extended number of years, but if the table, published in the report,* which embodies the results of different plots of new varieties for 1903-5, be examined, it will be found that White Transparent comes out eightieth on the list of those cultivated in black soils, while the Bourbon is still lower.

It has often been urged that these results are based upon small plots, which do not furnish a sufficient quantity of cane for the tests to be of value to sugar planters, but tables are also given in the above-mentioned report which show that seedlings B. 147 and B. 208 are giving better results than White Transparent when grown on an estate scale. These tables have been furnished through the courtesy of Mr. A. Cameron, and embody the results obtained on certain estates in Barbados under his direction, on which canes of different varieties have been grown, and show comparisons between 693½ acres of B. 147, 33 acres of B. 208, and 411 acres of White Transparent for the seasons 1903-5.

Jamaica.—Cousins, in his report on the work of the sugar experiment station in Jamaica for 1905, states that some very good seedling canes, resulting from naturally cross-fertilized seed, have been produced and are being submitted to a rigid selection.

About 3,000 seedlings are now being grown each year in Jamaica : therefore a series of Jamaica seedlings worthy of trial on an estate scale should soon be available.

In the trials of the imported varieties, B. 208 gave a tonnage of 65·5 tons of canes per acre and is being recommended to planters 'as the most promising seedling cane at present grown in Jamaica.'

The author of the report also points out that about 100,000 plants of selected varieties were distributed during the past year, which clearly shows that the planters of Jamaica fully appreciate the introduction and trial of new varieties of canes.

Leeward Islands.—The results recently issued by the Imperial Department of Agriculture for the West Indies on the work carried on by Watts at Antigua show that B. 208 gave an average yield of 9,347 lb. saccharose per acre in plant canes and 5,001 lb. in ratoons, against 7,014 lb. in plant canes and 4,265 lb. saccharose per acre in ratoons of White Transparent. In St. Kitt's. B. 208 gave an average yield per acre of 8,675 lb. saccharose in plant canes and 6,648 lb. in ratoons against 7,014 lb.

* A brief summary of this report, together with the table referred to, will be found in the *West Indian Bulletin*, Vol. VI, pp. 341-60.

saccharose in plant canes and 5,861 lb. in ratoons of White Transparent, while B. 147 gave a yield of 7,133 lb. in plant canes and 6,174 lb. in ratoons.

As these figures are the mean results of a large number of plots carried on for four years in plant canes and for three years in ratoons in Antigua and for five and four years, respectively, in St. Kitt's, they show that seedling canes are of considerable economic value to planters in the Leeward Islands.

British Guiana.—In British Guiana, up to the beginning of 1905, nearly one-third of a million of seedling canes had been raised by obtaining seed from good standard varieties, and 26,000 of these had been selected for field experiments. Harrison, at the last West Indian Agricultural Conference (1905), stated that 14,800 acres were under cultivation with varieties other than Bourbon and of these about 13,000 acres were occupied by new seedling varieties, the favourite ones with the planters being D. 109, B. 147, D. 145, D. 625, and B. 208. It is estimated that D. 145 bears a ratio to the Bourbon in respect to saccharose yield per acre as 170·8 is to 100.

At the end of 1905 the area under cultivation in varieties of canes other than Bourbon extended to 18,000 acres, and as opportunity offers, further extension is being undertaken. This is nearly one-fifth of the acreage under cane cultivation in British Guiana, and shows that planters have been ready to appreciate what has been done for them in the matter of new varieties of canes. The average returns on an estate of over 5,500 acres show that seedling canes, tested over a period of five years on an area of over 2,000 acres, gave nearly 26 per cent. more sugar than the Bourbon cane under similar conditions.

In an official report presented in May 1906 by Harrison on the Sugar-cane Experiments carried on under his direction at British Guiana, he states: 'Some measure of the success of the administration of the Imperial grant-in-aid for the West Indies may be found in the extension of the area occupied by new seedling varieties in the colony from about 550 acres in 1899, to 20,065 in 1906, and in that during the last five years we have recorded that new varieties of seedling canes have given, over large areas, mean results of 8, 10, 22, and 35 per cent. higher than the average of the returns obtained from the Bourbon during the same period.'

Two Demerara seedlings have also shown their superiority in many respects to the home canes in Louisiana.

Trinidad.—In Trinidad, experiments on a small scale have been carried on with seedling canes, and reports show that D. 95 has given an average return of 23·65 tons of cane per acre, as against an average of 21·33 tons per acre for White Transparent and 16·43 tons per acre for the Bourbon.

By closely examining these results obtained throughout the different portions of the West Indies, it will be realized that seedling canes are likely to prove an important economic factor in the improvement of the sugar industry. Much has already been accomplished, but it is expected that in the future canes of still higher value will be raised.

Hybrids in Barbados.

The experimental work begun by Lewton-Brain in 1904 in artificial cross-pollination and self-fertilization proved successful, and therefore in 1905 systematic attempts to raise new hybrids were commenced.

Crossing was performed in two directions, the pollen parent in one cross being used as the seed parent in the other cross; in other words, one variety was utilized as the female parent in one cross and as the male parent in the other.

'The arrow which was to become the seed parent was carefully selected on a cane free from disease, bagged before it began to emerge from the leaf-sheath, and allowed to remain until a length of at least 6 inches presented itself in the air and to the rays of the sun. It was found that very young spikelets were affected seriously by the sun after they had been operated upon, but that, if they remained exposed until the glumes were beginning to turn slightly red, they stood the severe handling much better. Careful microscopic examination of the flowers at this stage revealed very little mature pollen in the anthers, and the stigmata were not in a receptive condition, being still in the white, immature state. There could, therefore, be no danger of self-fertilization. It was also found that if the spikelets happened to present a lateral view, the glumes could easily be separated, and the anthers removed without rupture.'

Only those canes which had stood the strongest tests on a large scale for a number of years were used in the experiments. Over 600 spikelets were emasculated and artificially pollinated, of which over 400 were spikelets of B. 147 and B. 208.[16]

The results of this work have not been satisfactory, as an unfavourable season with windy, showery weather destroyed all chances of good success.

Some further particulars of the results obtained by Lewton-Brain in 1904 in Barbados may be interesting. He experimented with some of the best Barbados varieties as the parent plants and as a result obtained five hybrids of known pedigree. These have been carefully grown, and although it is impossible at present to say what their commercial value will be, yet it may be interesting to record a few external features that have been noticed during the growing season.

The pedigree seedlings that have been obtained consist of the following* :—

(1) Three holes of B. H. 1 : cross between B. 1,376 x B. 1,529
(2) One hole of B. H. 15 ; „ „ B. 3,289 x B. 1,529
(3) One hole of B. H. 18 ; „ „ B. 3,289 x B. 1,355

DESCRIPTION OF PARENTS.

In the following description of the varieties used in hybri-

* In the description of the crosses that gave hybrids the seed-bearing parent is always given first and the pollen-bearing parent second, thus: cross between B. 1,376 x B. 1,529 implies a cross between B. 1376 as seed-bearing parent or female parent and B. 1,529 as pollen-bearing or male parent.

B 147.

B 208.

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dizing only the more important characteristics are noted and are chiefly those which can be used in comparing with the descriptions of the hybrids :—

B. 1,376.—Germinating power, good ; colour, dull yellowish-green ; habit of growth, more or less recumbent ; internodes, cylindrical ; eyes round ; dried leaf-sheaths fall readily ; disease resistance fair.

B. 1,529.—Germinating power, under average ; colour, red ; habit of growth, upright ; internodes variable but generally roundish ; eyes round ; dried leaf-sheaths somewhat adherent ; disease resistance good.

B. 3,289.—Germinating power, fair ; colour, yellowish-green ; habit of growth, recumbent ; internodes cylindrical ; eyes round ; dried leaf-sheaths fall readily : disease resistance very good.

B. 1,355.—Germinating power fair ; colour, red ; habit of growth, generally upright ; internodes variable, but generally roundish ; eyes round ; dried leaf-sheaths fall readily ; disease resistance fair.

DESCRIPTION OF HYBRIDS.

Cross 1.—B. 1,376 × B. 1,529.—Owing to some differences in the three holes of the cross B. 1,376 × B. 1,529 it has been proposed to cultivate them separately under different nomenclature. The following are the characters :—

B. HH. 1 = B. HH. 3 :—Colour, yellowish-green ; habit of growth, recumbent ; internodes roundish ; eyes round ; dried leaf-sheaths somewhat adherent ; disease resistance fair.

B. HH. 2 :—Colour, yellowish-green ; habit of growth, upright ; internodes variable ; eyes round ; dried leaf-sheaths fall readily ; disease resistance fair.

All the canes from this cross were yellowish-green in colour, thus resembling the seed-bearing parent B. 1,376, and not B. 1,529, which is a red cane. The canes of two holes of this cross were recumbent in habit of growth, taking somewhat after B. 1,376, while the canes of the other hole were upright—a characteristic of B. 1,529. The canes were all above average size, therefore resembling B. 1,376 rather than B. 1,529, which is a thinnish cane ; but they possessed internodes which resembled closely those of B. 1,529. Two-thirds of the canes also resembled B. 1,529 in that they had leaf-sheaths which were somewhat adherent to the stem.

Cross 2.—B. 3,289 × B. 1,529 = B.H. 15.—Colour, yellowish-green ; habit of growth, upright ; internodes roundish ; eyes round ; dried leaf-sheaths somewhat adherent.

The canes of this cross died early through the effects of the excessive drought that has been lately experienced and therefore the characteristics could not be closely followed.

Cross 3.—B. 3,289 × B. 1,355 = B.H. 18.—Colour, yellowish green ; habit of growth, slightly recumbent ; internodes variable, but generally roundish ; eyes round ; dried leaf-sheaths adherent ; disease resistance fair.

The canes of this cross were drought resistant and resembled in colour and habit of growth B. 3.289, in the shape of internodes B. 1,355, but differed from both parents in possessing adherent leaf-sheaths.

Owing to the unfavourable season, during this last year, it was thought advisable to cut up all the canes available from these crosses and not to submit any of them to chemical analysis and, therefore, it is impossible, at present, to say what will be the commercial value of these canes. During this next year the characters of the hybrids will again be closely followed and recorded in order to see if any of them are variable.

SELF-FERTILIZED SEEDLINGS.

In 1904, several arrows of the better varieties were also bagged to obtain self-fertilized seedlings in order to investigate, if possible, some of the dominant characteristics of our different varieties of sugar-cane. B. 1,529 gave forty-two seedlings, which showed the following variations :—*

Weight of canes per hole—extremes		5 lb.	to	47 lb.
Saccharose per gallon	,,	1·256 ,,	,,	2·398 ,,
Glucose per gallon	,,	·028 ,,	,,	·139 ,,

It also showed that its red colour was a recessive character, a fact which is borne out by the seedlings obtained by the cross between it and B. 1,376. It might also be thought that its upright habit is also recessive, for the self-fertilized seedlings presented habits, recumbent to upright, in the ratio of 3 to 1. One of its dominant features is the inherent richness of its juice—a fact already noticed—when compared with the analysis of the juices of other seedlings grown under similar conditions.

B. 1,376 gave twenty-seven seedlings that also varied considerably as may be seen by the following table :—

Weight of canes per hole—extremes		8 lb.	to	50 lb.
Saccharose per gallon	,,	1·196 ,,	,,	2·015 ,,
Glucose per gallon	,,	·039 ,,	,,	·156 ,,

It is impossible at present even to speculate upon its various characteristics, as the seedlings were so varied, but most of them were yellowish-green in colour and somewhat recumbent in habit of growth.

In all, sixty-nine self-fertilized seedlings have been investigated and, therefore, it may be held that the results above given have been deduced from a very small number, but they clearly show that much can be learnt about the inheritance in the sugar-cane by inquiring into the dominant and recessive characteristics of the different varieties, and then it may be possible to build up an ideal cane.

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* These figures were obtained from Prof. J. P. d'Albuquerque, Chemist in-charge of Sugar-cane Experiments, and Mr. J. R. Bovell, Agricultural Superintendent, Barbados.

Other Countries.

Although, in other countries, seedling canes have not been raised systematically, yet records show that introduced seedlings are giving satisfactory results in all places where they are cultivated.

In Pernambuco, Brazil, seedlings were first attempted to be raised in 1890,[17] and in 1899 it was reported that a seedling cane was giving excellent returns. It was, at first, immune from the 'gumming' disease, but after cultivation for some time it became more or less liable to the attacks of this disease. Since then other seedlings have been produced, which possess a greater immunity from disease.

In Natal, West Indian seedlings, B. 109 and D. 95, sent from Antigua, have made satisfactory growth and are being cultivated on increasing areas throughout that colony.[18]

In Fiji, it is stated by Knowles in his reports during 1905, 35 acres of different varieties of canes are being grown for trial and for hybridization experiments. This is possibly the first time that such experiments have been conducted in Fiji, and good results are being looked for.[19]

In Martinique, many of the West Indian seedlings as well as many home seedlings are giving larger yields of sugar per acre than the standard varieties.[20]

In Réunion, there are large numbers of different varieties of canes under cultivation, but no mention of systematic attempts at raising seedlings can be found.[21]

GENERAL CONCLUSIONS.

In conclusion, it must be held, after careful examination of the various results, that the production of new varieties of canes by selection and hybridization has proved a valuable means of improving the quality of the sugar-cane. The experiments carried on in the West Indies are most encouraging, for it has been shown that not only are the seedlings more resistant to certain classes of diseases through their increased vigour and growth, but that they also give a larger yield of sugar per acre: and the results from Java, Hawaii, Queensland, Louisiana, and elsewhere all confirm those obtained in these islands.

The success of the results already obtained should stimulate workers in this subject to greater efforts in the production of new races of canes, for it is not only necessary to improve the productiveness of the plant, but it is essential that races of greater disease resistance be raised, for whereas many of the seedlings at present are immune from one disease, they are more or less susceptible to another, and also that a large number of varieties be at the disposal of cane planters, owing to the great differences in climate and soils of cane-producing areas.

That climate and soil are the paramount influences exerted in the sugar-producing capacity of different varieties has clearly been shown by the difference in yields and other characteristics manifested by the same cane in different localities.

Therefore, following the example of European beet growers who think that the practice of persistently growing their crops under the same conditions of soil and climate is a mistake, the seedling canes are distributed in experimental plots on widely different areas and under different conditions. The seedlings are also grown in competition for a number of seasons before any definite conclusions are drawn as to their relative value, owing to the varying time of their maturity and the rapid deterioration of over-ripe canes, and the varying germinative power of the seed cuttings.

Whereas considerable improvement has been made by selection and natural hybridization, it is expected that hybridization under control should give desired results more rapidly, for by the careful choice of parents it is hoped to combine some of the good qualities of both parents in the offspring.

The chief difficulty against obtaining large numbers of hybrids has been due to the small size of the flowers and the general habit of growth, but by careful manipulation, as described in the *West Indian Bulletin*, Vol. V, pp. 362-3, and Vol. VI, pp. 394-402, these difficulties can be surmounted, and good results should follow in seasons favourable to hybridization experiments.

The increasing fertility of the newer seedlings—as shown by the fact that recently nearly 1,000 seeds from a single inflorescence have been known to germinate, whereas a few years ago thirty to fifty was the greatest number recorded—makes it probable that many of the difficulties that have previously kept this work in check will sooner or later be overcome.

Probably the greatest improvement in the future will result from first analysing the different characteristics of the varieties to be used as parent canes by raising large numbers of self-fertilized seedlings and then building up an ideal cane, which will stand the rigorous tests of field selections, and analysis in the laboratory. In the carrying out of this work, great variations will be noticed owing to the hybrid origin of the varieties to be used for crossing purposes; but, then, by raising large numbers of self-fertilized seedlings, the heredity value of the parent varieties may be learnt from careful analyses of the offspring. In other words, an examination of varieties of canes for the so-called 'centgener power' of Hays may be of practical importance.

In short, 'the great expectations once held of seedling canes may not have been realized,' yet 'the greatest hope for the future lies in the expectation that it may become increasingly practicable to raise canes of definitely known parentage from carefully selected plants possessing to the greatest degree the characteristics of disease resistance, high sucrose yield, heavy tonnage of cane, and the other properties which have been previously mentioned as marking a sugar-cane of high economic value.'[22]

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DISTRIBUTION OF ECONOMIC PLANTS BY THE BOTANIC STATIONS IN THE WEST INDIES.

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An important branch of the work entrusted to the Imperial Department of Agriculture for the West Indies has been the maintenance of Botanic and Experiment Stations, for which grants-in-aid have been provided. Such stations are in existence at Tobago, Grenada, St. Vincent, St. Lucia. Dominica, Montserrat, Antigua, St. Kitt's-Nevis, and the Virgin Islands. There is also a Botanic Station in Bardados.

Detailed reports upon the work carried on at these stations, together with reports upon (in the case of St. Vincent, St. Lucia, and Dominica) the Agricultural Schools established by the Department, and also in connexion with efforts to promote the teaching of agricultural principles in secondary and elementary schools, and agricultural instruction generally, have been published each year. As stated in a recent issue of the *Agricultural News* (Vol. V, p. 328), 'these reports form an interesting summary of the efforts for the improvement of agriculture in the several islands; for, in addition to dealing with the details of the work in the Botanic Stations, the local officers have prepared valuable reports on the progress in the establishment of minor industries and experimental work in connexion therewith.'

As is well known, these Botanic Stations contain valuable collections of economic and ornamental plants, which are of considerable interest to all visitors to the several islands, while they are also much appreciated by the residents of the islands as places of resort in the cool of the evening. Further, these institutions have proved of value to planters and peasants who may have desired to obtain information in regard to the cultivation of a great number of tropical products—information which the officers-in-charge have always been ready to afford. This facility has been particularly appreciated by new-comers and intending settlers, who have thus been saved, in many cases, the cost of expensive experiments.

The value of these institutions, in the absence of private nursery establishments, such as exist in northern latitudes, has perhaps been especially realized in connexion with the distribution of economic plants; for at all these stations nurseries are maintained for the purpose of raising plants for sale or gratuitous distribution. Planters and settlers who may not have had facilities for raising their own plants have thus been enabled to get a start of several months in laying out plantations.

Not only have the Botanic Stations been able thus to render much assistance in the establishment of new industries, but also, in the case of established industries, planters have

had the opportunity of obtaining seedlings of the best varieties of economic plants, raised under the best conditions, and free from fungoid and insect pests. To avail themselves of these advantages planters have not been slow. Consequently, the demand for plants has gone, in some cases, beyond the means of the stations to supply. As is mentioned below, in the case of the Dominica Botanic Station, the Curator has been obliged to call upon the planters to start their own nurseries, as it will no longer be possible to meet the large demands for some plants, like limes, which will now have to be reserved for the benefit of new-comers.

In an article on the 'Cacao Industry in the West Indies,' in the *West Indian Bulletin*, Vol. V, pp. 172-7, reference was made to the important part played by the various botanical establishments in the remarkable progress that was there recorded. With the view of indicating the very considerable extension of cacao plantations in recent years in the West Indies, it was shown that from the Botanic Stations at Dominica, Montserrat, St. Lucia, St. Vincent, and Tobago no fewer than 20,608 cacao plants had been distributed during the year 1902-3, and 29,874 in the year 1903-4.

Similarly, in connexion with the progress of rubber planting, which was reviewed in the *West Indian Bulletin*, Vol. VI, p. 147, there were distributed from the Botanic Stations at Dominica, St. Lucia, Montserrat, and Tobago, in the year 1902-3, 1,955 plants of *Funtumia elastica* and *Castilloa elastica*, and in the following year, 7,767 plants of these two species, in addition to quantities of seed of both in both years. In all the islands where rubber trees are growing, the Botanic Stations have obtained seeds and raised plants for distribution.

In the following pages, therefore, an attempt has been made to show the relative importance of this branch of the work of the West Indian Botanic Stations, and at the same time to indicate, to some extent, its influence on planting enterprise generally.

It will be seen that the station at Dominica, under the charge of Mr. Joseph Jones, has been particularly successful in this important work, while the similar institution at St. Lucia, in conjunction with the nurseries at the Agricultural School, has been a great boon in furthering the extension of plantations and the opening up of new areas for agricultural operations. One is undoubtedly forced to the conclusion that, if for no other reasons, the Botanic Stations under the direction of the Imperial Department of Agriculture for the West Indies have justified their existence by reason of the great assistance of this nursery work to the planting community.

In addition to the distribution of young seedlings, large quantities of seed of various economic plants have also been distributed from all the Botanic Stations. In this connexion, these institutions have been particularly useful in assisting in the establishment of the cotton industry, while onion seed has been regularly obtained by the Imperial Department of Agriculture to be sold at the various stations.

Cacao pods have been distributed in large quantities from the stations at St. Vincent and Dominica; nutmegs at St. Vincent; seed of rubber-yielding plants at Dominica. In connexion with the experiments with varieties of sugar-cane conducted by the Department in Barbados and the Leeward Islands, cuttings of selected varieties have been regularly distributed to planters.

Teachers in charge of elementary schools have received every encouragement and assistance from the Botanic Stations in establishing school gardens. Not only has advice been freely given by the local officers in the choice of suitable locations and such matters, but vegetable seeds and plants have in many cases been presented. Thus, last year, 385 plants, in addition to 218 packets and 5 ℔. of seeds, were distributed free to school gardens in St. Lucia, and vegetable seeds were regularly supplied for the same purpose in St. Vincent.

Planters have also much appreciated the assistance of the Botanic Stations in supplying budded or grafted plants of fruit trees. This has enabled them to obtain the best varieties of citrus plants, mangos, etc. As comparatively few estates have employés who are capable of carrying out this important work, planters have been obliged to rely upon the Botanic Stations for a supply of such plants. With the training of pupils at the Agricultural Schools and at some of the Botanic Stations in the operations of budding and grafting, it should be possible, in the course of time, and as the advantage of budded and grafted plants over seedlings secures its due recognition, for planters to obtain the services of proficient budders and grafters and so have this work carried out on the estates.

Last year, 692 plants were successfully budded by the pupils of the Agricultural School at Dominica, while thirty plants of grafted mangos were raised. At the St. Lucia Agricultural School, 550 budded orange plants were raised last year by the boys. As mentioned below, budded citrus plants occupy an important position in the lists of plants distributed from some of the Botanic Stations, while there is also a steady demand for grafted mango plants.

The principal functions performed by Botanic Stations are briefly summarized as follows in the *Annual Colonial Report* on the Leeward Islands for 1903-4:—

'Botanic Stations, or their equivalents, are established in every presidency, and herein are conducted experiments with, and experimental cultivation of, various plants adapted to local conditions, either with the object of improving the cultivation of established kinds, or of introducing improved varieties or entirely new plants, with the hope of establishing new industries. These stations serve as centres from which economic plants are distributed to local cultivators, who readily avail themselves of the facilities thus offered.'

It should be added that similar work, on a comparatively large scale, has also been carried on by the Botanical Departments in Jamaica, Trinidad, and British Guiana.

It is now proposed to review briefly the plant distribution work of the several stations during the last five years.

TOBAGO.

The nursery work at the Tobago Botanic Station has been gradually extending, and the number of economic plants distributed has steadily increased, during the last five years, from 4,550 in 1901-2 to 9,538 in 1905-6. The total number of plants distributed during the five years is 38,673. Cacao plants are principally in demand, 19,178 having been distributed in the last four years. There is also some demand for fruit trees, last year's list showing that 2,682 were distributed. Since the prices of nursery stock were reduced, budded oranges and grafted mangos have been much in demand. In the four years 1902-6, 1,589 rubber trees have been distributed, while there is a small but fairly constant demand for coffee and spice plants and for shade and timber trees.

GRENADA.

The demand for economic plants at the Grenada Botanic Station is not large. Formerly, ornamental plants were raised for distribution in large numbers, but now the nursery work is confined to raising economic plants to order. The numbers of economic plants distributed in Grenada during the past five years are: 1901-2, 8,794; 1902-3, 7,584; 1903-4, 5,657; 1904-5, 3,534; 1905-6, 4,532: total 30,101. Of the number distributed last year, 2,600 were cacao plants. The only other plants much in demand were pine-apple suckers, of which 464 (Black Antigua variety) were sold, and *Castilloa elastica*. In addition, some 7,000 plants of seedling sugar-cane D. 95 were distributed.

ST. VINCENT.

We find that in the year 1901-2 no fewer than 24,033 economic plants were distributed from the Botanic Station. The next year, in consequence of the nursery work being hampered by the volcanic eruptions, the number fell to 7,670. Since then considerable progress has been made, and the average number of plants distributed during the last three years is 19,112, or a total of 89,038 for the five years. Last year, the great interest evinced in cotton planting appears to have been responsible for a decrease in cacao planting, if we may judge from the smaller demand for cacao plants.

Since the volcanic eruptions there has been extensive planting of cacao, and the returns show that 41,392 plants have been distributed from the station during the last three years, in addition to 149 cacao pods.

In reference to the distribution of cacao plants in St. Vincent, the Agricultural Superintendent stated in a paper recently read before the Agricultural Society :—

'At the Botanic Station we select pods for distribution only from the Forastero type, although we were some time ago credited with distributing the Criollo, a variety of which we have not a single true specimen, but which, if it can be grown,

is the most valuable variety of all; but it is very difficult to grow. Since my arrival I have paid special attention to this matter of the selection of pods for seed purposes: when pods of desirable type have not been available at the Botanic Station, I have obtained supplies from Government House and Queensbury estate to meet requirements. A large number of pods and plants have been sent out each year to planters in different parts of the island, the results of which distribution should soon be evident.'

During 1905-6, 3,500 plants of selected varieties of sugar-cane were distributed.

The free distribution of plants in connexion with the Land Settlement Scheme is also worthy of mention. In 1902-3, 402 economic plants were granted to the allottees; in 1903-4, 5,325; in 1904-5, 15,424; and in 1905-6, 11,770; making a total of 32,921 plants distributed during the last four years. The plants most in demand by allottees are cacao, nutmegs, and coffee.

BARBADOS.

Mr. J. R. Bovell, F.L.S., F.C.S., Superintendent of Agriculture at Barbados, has kindly furnished figures which show that, during the five years 1902-6, there were distributed from the Botanic Station to places abroad 34,945 yam plants of various varieties, 262 ℔. of sweet potatos, 445 ℔. of eddos, 718 banana suckers, quantities of vegetable seeds and tubers, seeds of leguminous plants, etc., etc. There were also sent abroad 73,545 cane plants and 1¼ tons of seedling cane B. 208.

Locally, there were distributed in the same period, 812 cassava cuttings, thirty-eight banana suckers, fourteen avocado pears, and sixteen grafted mango plants. The number of cane plants distributed was 5,653, while 2,064 palms and other ornamental plants were sold.

The importance of this station as a distribution agency is shown by the long list of plants imported and distributed locally during the five years. Mention may be made of the following: grafted mangos, 147; budded citrus plants, 138; lemon plants, 25; nutmegs, 50; and cacao, 50. The total number of such economic plants distributed is 413, in addition to the following: 663 pine-apple suckers, 224 cocoa-nuts, 136 ℔. of yampies (Indian yam), 36 barrels of Irish potatos (Bliss Triumph variety), 648 ℔. of onion seed, and 2½ ℔. of tobacco seed.

It may also be stated that 9 barrels of mahogany seed were sent to the Royal Botanic Gardens, Kew, for the Government of India.

ST. LUCIA.

In St. Lucia, plants are raised for distribution at the Agricultural School as well as at the Botanic Station.

The demand for economic plants from the Botanic Station in St. Lucia has shown much variation. In the year 1901-2, 15,461 plants were distributed; but the next year this number rose to 26,637—the highest figure on record. This increase was due to the large number of lime plants supplied to two

estates, over 15,000 going to one of them. In 1903-4, there was no demand for lime plants, and only 10,216 economic plants were distributed. The next year there was a slight increase, viz., to 13,103, although there were also supplied that year a large number of cane plants and pine-apple suckers. Coming now to last year's figures, we find that 25,675 plants were raised at, and distributed from, the nurseries at the Botanic Station and the Agricultural School, showing an increase of 16,380 on the number distributed from the same sources in the previous year. This was due to a very considerable demand for lime and cacao plants. The total number of plants sent out from these nurseries during the past five years is thus 91,092.

Closer analysis of the tables relating to the distribution of plants in St. Lucia shows that there has been a steady demand for cacao plants, the average number distributed during the past five years being 5,588, or a total of 27,940. The highest figure was reached last year, when 8,180 plants were sold at the nurseries or given to purchasers of Crown Lands, in addition to a considerable number of cacao pods.

In some years the demand for lime plants has also been large. As we have seen, no fewer than 16,350 were distributed in 1902-3; last year (1905-6), 11,834. There is apparently at the present time considerable interest being taken in lime cultivation; already during the current year (April to October 1906) 26,416 lime plants have been distributed from the nurseries at the Botanic Station and the Agricultural School. 'It is estimated that the 54,600 lime plants distributed during the five years 1902-6 are sufficient to plant, at 12 feet by 12 feet, and allowing for losses, about 150 acres.' (*Agricultural News*, Vol. V, p. 376.)

While these interesting figures are indicative of considerable planting enterprise in St. Lucia they are not, as Mr. Moore points out in his last annual report, any guide to the extent to which the cultivation of the various plants is being increased, as most planters find it more convenient and economical to raise their own plants, either 'at stake' or in nurseries on their estates.

At the Agricultural School regular instruction is given in budding oranges. Last year 550 budded plants were raised, the budding being done by the pupils. The distribution of seedling oranges has for some time been discontinued, and only budded plants are now supplied by the Department.

Included in the foregoing figures are the numbers of economic plants distributed from the Department nurseries free to purchasers of Crown Lands as follows: 1901-2, 2,352; 1902-3, 2,457; 1903-4, 1,278; 1904-5, 2,554; 1905-6, 3,077. During the five years 1901-6 there have been thus distributed 3,544 cacao, 1,679 coffee, 2,569 nutmegs, 412 rubber, and 814 kola plants. The total number of plants distributed to purchasers of Crown Lands during the five years is therefore 11,717. In his report for 1904, the Commissioner of Crown Lands states: 'The difficulty in transporting boxes of plants by the peasants, who must "head" them to their lands, deters many from availing themselves of this great advantage.'

The Botanic Station has also greatly assisted in the distribution of new varieties of sugar-cane: in the year 1904-5, it imported 19,700 seedling cane plants for this purpose. Last year the Cul-de-Sac factory imported 70,000 plants of seedling cane B. 208.

At the request of the Agricultural Society, the Department has arranged to supply 100 budded oranges and 100 grafted mangos for distribution to school gardens. These are intended to serve as stock plants to supply material for lessons in budding and grafting. Seeds of economic plants have been presented by the Botanic Station to all school gardens in the island.

DOMINICA.

The average number of plants distributed from the Dominica Botanic Station during the last five years is 56,726, with the remarkable total for that period of 283,631. Of this number considerably over a half have been lime plants, 154,562 having been distributed in the five years. In addition, 11,792 plants of the spineless lime have been sent out from the station during the same period. The second place is taken by cacao with a total for the five years of 64,601 plants, in addition to 9,909 pods. Of late years there has been a considerable extension of rubber planting, and we find that the Botanic Station has been supplying plants and seed of the Central American rubber (*Castilloa elastica*) and West African rubber (*Funtumia elastica*); 6,827 plants and 124 ℔. of seed of the former and 10,072 plants and quantities of seed of the latter have been distributed to planters during the four years 1902-6. The Curator also records an increasing demand for nutmeg plants and budded oranges.

So great has become the demand for lime plants that it is no longer possible for the station to supply the number required. In his last annual report the Curator says:—

'As time goes on planters are relying more and more on the station for lime plants, forgetting that there are limits to the capabilities of one small institution in a matter of this kind. It would be advisable for the garden to continue to raise a few thousand plants annually for sale to new settlers, who would then be able to get their lands planted quickly; but established lime estates could, with the exercise of a little forethought, raise all the plants required for extensions of the area of this cultivation.

'During the past six years over 200,000 common lime plants and 12,000 spineless lime plants have been distributed from the station. After allowing a percentage for loss, this number is sufficient to plant, at 15 feet apart, 1,000 acres of land.'

Particular interest attaches to the distribution of spineless limes from this station. The history of this variety is as follows: A lime tree on Shawford estate, Dominica, being noticed in 1892 to be free from the usual formidable spines, seeds were collected and sown. Some 75 per cent. of these came true, and the plot bore heavily in 1902, when Mr. Jones

found that 80 to 90 per cent. of the seedlings raised came true. In his report for 1901-2, Mr. Jones said of it: 'This variety differs from the ordinary lime cultivated in the island in having a more erect habit of growth, smaller fruits with fewer seeds, superior bearing qualities, and greater acidity of juice.'

The spineless lime has been analysed by Dr. Francis Watts and its composition compared with the ordinary lime as follows:—

	Spineless.	Ordinary.
Average weight of fruit ...	34·1 grams.	61·9 grams.
Percentage of juice	51·3 per cent.	50·8 per cent.
Sp. Gravity $\frac{30^\circ}{16{\cdot}16^\circ}$ C. ...	1·0410	1·0390
Total solids, grams per 100 c.c.	11·70	11·15
Citric acid „ „ „	9·82	8·87
„ „ oz. per gallon	15·71	14·18
Purity (i.e., ratio of acid to total solids) ...	83·9	79·5

Dr. Watts adds: 'From this it will be observed that the spineless lime is very much smaller than the ordinary lime, but its juice is richer and purer. The juice of the ordinary lime now examined is, however, somewhat low in purity. The point now to be ascertained is whether the spineless lime will bear such a quantity of fruit as to compensate for the smallness in size.'

The number of spineless lime plants distributed in the year 1905-6 shows a large increase over the number sent out in any previous year. In his last report, Mr. Jones records the following interesting observations on the behaviour of this variety under cultivation:—

'During the year I had the opportunity of seeing fields of spineless limes just coming into bearing in one of the windward districts. It was pointed out that this plant, when about three or four years old, owing to its erect growth, formed rather a heavy top, and was at that age more likely to be overthrown by the wind than the ordinary variety. This tendency to elongate will be corrected as the trees come into bearing; the weight of the fruit will bring the branches down, and cause the trees to assume the same habit as the common lime.

'A close examination of spineless limes on several estates showed that there is no fear of the plants developing spines and reverting to the ordinary type. Plants of the intermediate variety, which have a number of blunt growths in place of the sharp spines of the ordinary lime, have been planted out and observed. In two or three years these plants have become spineless, showing that the tendency is to throw off spines and not towards developing them.'

Now that a trade has been started in Dominica in green limes, and the fruits have to be gathered from the trees instead of being allowed to drop to the ground, as when the limes are grown merely for the extraction of juice, the advantage of the spineless lime has been more fully realized. As Mr. Jones says:

'The merits of the spineless lime should be considered by shippers of green limes to the United States, where a large coarse lime is not required. The medium-sized, smooth-skinned, almost seedless, and juicy fruit of this variety, containing a large quantity of acid, should be just the thing required for that market. It is evident that green limes would be gathered much quicker, and with less damage, from trees devoid of spines than from the common formidably armed trees. At a time when complaints are frequent as to the condition in which the limes arrive in New York, anything that would tend to save the fruits from damage in picking seems worthy of attention from those interested in the trade.'

An important branch of the work at the Dominica Botanic Station has been the raising of budded stock of various varieties of citrus fruits. Since this work was undertaken 6,000 budded orange plants have been distributed, mostly of the Washington Navel variety. It is estimated that this number is sufficient, planted at 20 feet apart, for 60 acres.

Similarly, the best varieties of mangos have been grafted at the station for distribution, and there is always a ready sale for them. The following grafted varieties are grown at the station : Ceylon No. 1, Julie, Fifine Gabrielle, D'Or, Devine, Malda, Peters, Gordon, Peach, Minnie, and Amelia.

An experiment in connexion with the grafting of cacao carried out at this station gives promise of useful results. For this purpose the delicate Alligator cacao was grafted by approach on stocks of the Forastero. The grafting of cacao has been found to present very little difficulty, the union, under favourable conditions, being complete in five or six weeks, when the plants can be taken off and planted out. The first lot of grafted cacao plants, fifty in number, planted in September 1905, are reported to have made good growth. Besides having the advantage of giving fields of a uniform kind of cacao, grafting enables the planter to propagate from any tree which he may recognize as possessing specially good characters, such as resistance to disease, regular and heavy bearing, or yielding cacao of good quality. As Mr. Jones states: 'If rough stages were erected round such trees, on which to place stock of the common Calabacillo or Forastero, a large number of plants could be grafted by approach at one time.'

It may be mentioned, too, that the Agricultural School has also taken part in this work. Last year 3,000 lime plants were raised for distribution. Special effort has been made to train the boys in budding and grafting, and therefere most of them are now proficient budders. They find a ready sale for the results of their labours.

MONTSERRAT.

The total number of economic plants distributed annually from the Montserrat Botanic Station has varied as follows: 1901-2, 11,817: 1902-3, 19,737: 1903-4, 19,690: 1904-5, 14,887: 1905-6, 6,774; total for five years, 72,905.

As in the case of St. Lucia and Dominica, limes and cacao are the plants which this station is mostly called upon to supply. The demand for the former has been fairly constant, an average of 7,950 plants being sent out each year, or a total of 39,752 for the five years, that is, sufficient to plant some 110 acres. Of cacao plants 5,565 were distributed during the five years. During the same period 1,361 rubber plants (*Funtumia elastica* and *Castilloa elastica*) were distributed.

Special mention should be made of the useful work done at the Montserrat Botanic Station in distributing the best varieties of sweet potatos and cassava. Varietal tests of these crops have been carried on at the station for several years, and there is considerable demand for those varieties which have given the highest yields. Seedling canes have also been distributed from the station: in 1903-4, 15,176 cuttings of named varieties were so obtained by planters.

ANTIGUA.

Except for pine-apple slips and cuttings of cassava and sweet potatos, few economic plants are distributed from the Botanic Station at Antigua. The total number of plants, other than these, distributed from 1901 to 1906 was 15,330. There is a fairly constant demand for lime and other citrus plants, 9,388 of which have been distributed in the five years under review.

During the last two or three years the nurseries have afforded assistance in connexion with the re-afforestation scheme. In the year 1904-5, 10,000 seedlings were raised in the nurseries and planted in the re-afforestation plots; last year 3,000 plants were similarly planted.

In Antigua, as in Montserrat, useful work has been done in distributing seeds and cuttings of those varieties of certain economic plants which have given the best results in the experiment plots. Thus, 3,000 cuttings of cassava were sent out during the month of March 1906, while 800 cuttings of the best varieties of sweet potato were obtained from the experiment plots last year.

In regard to the important work of distributing cuttings of sugar-cane, Mr. H. A. Tempany, B.Sc., Acting Superintendent of Agriculture for the Leeward Islands, has kindly prepared the following memorandum for the purposes of this paper :—

'The Imperial Department of Agriculture, since its formation, has carried on the work of maintaining a nursery at Skerrett's for the propagation of selected varieties of seedling canes. This nursery has served the double purpose of supplying plants for the maintenance of the plots at the various experiment stations, and of being the means of supplying the planters with new varieties of cane for trial on a small scale on estates.

'Up to about two years ago it was the annual custom to

sell by auction, at a public meeting of planters, the variety canes in the nursery that were not used up in supplying experiment plots.

'Since that time the custom has been in abeyance owing to the fact that the number of canes left in the nursery after planting the experiment plots was small. It is, however, hoped to revive this custom shortly.

'In consequence of the temporary abandonment of the cane plant sales, small quantities of cane plants have been distributed during the past two years to planters.

'In this way 1,693 plants of cane varieties were distributed here from Skerrett's during 1906 as follows: D. 625, 550; D .74, 288; B. 306, 291; Sealy Seedling, 182; B. 156, 282; B. 208, 100.'

ST. KITT'S-NEVIS.

During the last two or three years efforts have been made to encourage the planting of cacao and rubber trees in St. Kitt's. To assist in this, seedlings have been raised at the Botanic Station. In the year 1904-5, '579 young cacao plants raised at the station and twenty-one pods received from Dominica were distributed to Molineux estate, where an attempt is being made to establish cacao on the ravines on the upper lands.' On the same estate were planted 439 plants of *Castilloa elastica* and 263 of *Funtumia elastica*, which had been raised at the Botanic Station. The successful growth of cacao trees at Molineux has led other estates to plant cacao and rubber, with the result that last year the Botanic Station supplied 439 cacao plants and 289 rubber plants. The planting of cacao and rubber in this presidency is likely to extend.

Here, as in Montserrat and Antigua, cuttings of cassava, sweet potatos, and other plants grown in the experiment plots are distributed gratis.

Since the year 1899 cuttings of the best sugar-cane varieties and seedlings have been regularly distributed to estates in St. Kitt's from the Botanic Station for experimental cultivation. From the following figures, kindly supplied by Mr. F. R. Shepherd, Agricultural Superintendent, it will be seen that the total number of cuttings so distributed in the eight years is 170,000:—

1899	23,500	1904	15,000
1900	19,600	1905	16,770
1901	24,000	1906	16,800
1902	34,930		
1903	19,400	Total ...	170,000

During last year a lime nursery was started at the Nevis Experiment Station, and several thousand plants were distributed.

VIRGIN ISLANDS.

In the nursery at the Experiment Station at Tortola cacao plants are raised for distribution. Last year 300 plants of the Forastero variety were distributed. The station has served a very useful purpose in obtaining cuttings of seedling canes for planting in the Virgin Islands. In the year 1903-4, 2,000 plants of B. 147 were obtained from St. Kitt's and distributed. The following year 6,000 cuttings and plant tops of seedling varieties were imported from Antigua, the varieties being B. 208, B. 306, B. 109, and Sealy Seedling. About 3,000 were planted at the station, and the rest distributed. Last year 1,500 seedling cane plants were distributed.

Each year a number of pine-apple suckers have been distributed ; latterly, also, onion seedlings and a few rubber plants.

DISTRIBUTION OF PLANTS IN CONNEXION WITH ARBOR DAY CELEBRATIONS.

During the past few years, the celebration of Arbor Day has come to be a regular annual feature in most of the West India Islands. In all cases valuable assistance is rendered by the Botanic Stations, in the nurseries of which plants are raised for official and private planting on Arbor Day. The plants thus distributed comprise ornamental, shade, and economic trees.

The trees most commonly chosen for this purpose are palms (principally the cabbage palm and the royal palm, *Oreodoxa oleracea* and *O. regia*), mahogany, and white wood (*Bucida Buceras*). There is a wide choice of suitable trees in the West Indies both for ornamental and shade purposes. There are also very desirable fruit trees for gardens and orchards.

In Tobago, 216 plants were distributed free from the Botanic Station to managers of schools and others for planting on His Majesty's birthday, November 9, 1905.

With a view to encouraging the observance of Arbor Day in Barbados, in 1906, there was published at an early date in the *Official Gazette* a list of plants available for distribution, some 2,143 in number, with an intimation that persons desirous of observing Arbor Day could obtain plants by applying to the Superintendent of the Botanic Station. To this there was a hearty response, and, in all, 791 plants were delivered. Of this number, 303 were palms.

In Antigua, very complete arrangements have been made during the past few years for the observance of Arbor Day. These arrangements are in the hands of the Central Arbor Day Committee, which has recently been made permanent by the Government, thus ensuring the annual observance of Arbor Day, and, at the same time, providing a body which is

responsible for the upkeep and care of the trees planted. On November 9, 1905, 105 plants, raised at the Botanic Station, were planted. The trees planted in the largest numbers are mahogany, date palm, Christmas bush or bay tree (*Pimenta acris*), and cinnamon.

For the celebrations at St. Kitt's on November 9, 1906, 150 plants of various kinds were distributed to the schools throughout the island, while ninety mahogany trees were supplied for the official function in Basseterre.

TOTAL NUMBER OF ECONOMIC PLANTS DISTRIBUTED FROM THE WEST INDIAN BOTANIC STATIONS, 1901-6.

Station.	1901-2.	1902-3.	1903-4.	1904-5.	1905-6.	Total.
Tobago ...	4,550	7,605	7,445	9,535	9,538	38,673
Grenada ...	8,794	7,584	5,657	3,534	4,532	30,101
St. Vincent ...	24,033	7,670	13,536	26,256	17,543	89,038
Barbados * ...	...	...	...	...	...	...
St. Lucia ...	15,461	26,637	10,216	13,103	25,675	91,092
Dominica ...	60,533	57,131	53,500	46,736	65,731	283,631
Montserrat ...	11,817	19,737	19,690	14,887	6,774	72,905
Antigua ...	6,465	2,961	1,928	1,415	2,561	15,330
St. Kitt's ...	...	...	...	1,377	860	2,237
Virgin Islands†	...	...	...	...	...	...

* See p. 378.
† See p. 385.

LEAF BLISTER-MITES.

In most of the West India Islands in which cotton is being grown the leaf blister-mite (*Eriophyes gossypii*) has proved a serious pest. An account of the cotton leaf blister-mite was first published by Mr. H. A. Ballou, M.Sc., Entomologist on the staff of the Imperial Department of Agriculture, in the *West Indian Bulletin*, Vol. IV, pp. 282-6, while additional information was given later in the same volume (pp. 336-44). The following scientific description of *Eriophyes gossypii* was published by Mr. N. Banks in the *Journal of the New York Entomological Society*, for March 1904 :—

'Sir Daniel Morris, Imperial Commissioner of Agriculture for the British West Indies, recently brought to the Division of Entomology some mite-galls on cotton from Montserrat. Mr. Ballou had preserved some of the mites on slides. Upon examining the material, I find that the galls are caused by a mite, a species of *Eriophyes*, which I propose to call *E. gossypii*. The cotton leaves were very heavily infested with the galls, so much so that many were a mass of roughened swellings, curled and distorted. Within the recesses of these galls the mites were found in abundance, together with many eggs. The damage to the cotton was so severe that a great deal of it was thrown into the sea. Mr. Ballou, in the *West Indian Bulletin*, Vol. IV, p. 282, has given an account of the species. He recommends that the weeders working in the field be supplied with bags in which to put infested leaves, the bags, when filled, to be placed in boiling water.

Eriophyes gossypii, n. sp.

'Body elongate, cylindrical, and tapering; about six times as long as broad; abdomen with about seventy rings; two pairs of bristles on lower sides, one at about middle of length, the other half way from this to tip. At the tip there is a truncate plate, from each outer corner of which arises a long curved bristle. Dorsum of cephalothorax subtriangular, the sides slightly undulate, and in front truncate; above with three irregular, sub-parallel ridges each side, the inner one the longest. Legs short, the femora slightly thickened near base, a long bristle near tip of tarsus. In galls on cotton leaves, island of Montserrat, West Indies.'

In the course of his investigations of this pest, Mr. H. A. Ballou, M.Sc., has obtained specimens of similar pests on other plants. This material was forwarded for examination to Professor Alfred Nalepa, of Vienna. In most cases these blister-mites proved to be new species, three of which were described by Dr. Nalepa as *Eriophyes Morrisi*, *E. bucidae*, and *E. striatus*, respectively. Dr. Nalepa has also described other species sent to him from Fiji.

For the purpose of placing these descriptions on record in the *West Indian Bulletin*, they have been translated by Mr. John Belling, B.Sc., from the *Bulletin of the Royal Academy of Science*, Vienna, Nos. XIII and XXV, and other publications:—

Eriophyes Morrisi, n. sp.

Body small, cylindrical to slightly spindle-shaped. Shield semicircular. Markings on the shield not clearly discernible in the specimens available. Dorsal setae a little shorter than the shield. The knobs from which these spring, at the edge of the shield, not projecting over the posterior margin. Rostrum short, directed obliquely forward. Legs short, the two last tarsal joints of nearly equal length. Feathered seta with four pairs of pinnae. Claw a little longer than this. Femoral setae fairly long and fine. Sternum simple, not reaching the inner angles of the epimera. Second thoracic setae inserted in front of the inner angles of the epimera. Abdomen plainly ringed (about forty-two rings) and dotted. The dorsal half-rings in front of the caudal lobe are broader and smooth. Lateral setae fine, as long as the dorsal setae, inserted posteriorly to the epigynium. First ventral setae double the length of the shield, stout: second ventral setae about as long as the rostrum, fine: third ventral setae stout, equalling the shield, generally extending over the caudal lobe. Caudal setae very long, equalling about two-thirds of the body length. Accessory setae long, stiff. Epigynium, basin-shaped; genital setae laterally inserted, a little shorter than the second ventral setae. Covering lobe striped lengthways. Epiandrium bracket-shaped. Female, 0·14 mm. long and 0·033 mm. broad. Male, 0·11 mm. long and 0·032 mm. broad. Produces very small hemispherical galls on the upper side, and more rarely on the under side of the leaves, and on the leaf stalks of *Acacia* sp. (Montserrat, West Indies: sent by Sir D. Morris, Imperial Commissioner of Agriculture, Barbados.)

Eriophyes bucidae, n. sp.

Body extended, cylindrical; shield semicircular: anterior edge obtuse-angled. Shield markings comprise at the middle three longitudinal lines converging anteriorly, and at the sides many longitudinal curved lines. Dorsal setae directed outwards, very fine and shorter than the shield. Their swollen insertions are near one another in front of the posterior edge of the shield. Rostrum short, directed forwards and downwards. Legs short; the two last tarsal joints very short and nearly equal. Feathered seta with four (?) pairs of pinnae. Claw a little longer than this. Sternum simple. Epimera shortened. Second thoracic setae inserted in front of the inner angles of the epimera. Abdomen with closer rings (about sixty-two rings) and closer dotting dorsally than ventrally. The dorsal half-rings immediately anterior to the caudal lobe, somewhat broader and smooth. Lateral setae equalling the dorsal setae, very fine, inserted behind the epigynium. First ventral setae nearly double as long as the shield; second ventral setae a trifle shorter than these; third ventral setae somewhat shorter than the lateral setae. Caudal setae short, about as long as the first ventral setae; accessory setae absent. Epigynium very large, placed far forward, basin-shaped. Covering lobe curved, finely striped longitudinally. Genital setae not inserted on elevations, very short and fine. Epiandrium the shape of a pointed arch. Female, length 0·15 mm., breadth 0·03 mm. Male, length 0·11 mm., breadth 0·03 mm. Induces growths of hairs (erineum)

on the under side of the leaves of *Bucida Buceras* L., which fill up blister-like swellings of the leaf-blade. (Barbados; sent by Sir D. Morris.)

Eriophyes striatus, n. sp.

Body small, cylindroidal. Shield triangular, crossed by many close longitudinal lines. Swellings on which shield-setae are inserted distant from one another, at the edge. Dorsal setae equalling the shield. Rostrum short. Feathered seta with four (?) pairs of pinnae. Sternum not forked. Second thoracic setae shifted far forward. Abdomen with fine rings (about seventy rings) dotted. Lateral setae inserted somewhat behind the epigynium, equalling the dorsal setae. First ventral setae twice as long as the shield. Second ventral setae very short. Accessory setae absent. Epigynium hemispherical. Covering lobe smooth. Genital setae rather shorter than second ventral setae, inserted laterally. Female, length 0·14 mm., breadth 0·032 mm. Produces a brown felt of hairs in swellings on the leaves of *Eupatorium odoratum*. (Sent by H. A. Ballou, Barbados.)

LEAF BLISTER-MITES FROM FIJI.

In reference to the foregoing descriptions of West Indian leaf blister-mites, the following translation of an article by Dr. Nalepa in the *Journal of Economic Biology*, Vol. I, No. 4, on two new species of *Eriophyes* from the Fiji Islands, is likely to be of interest:—

Eriophyes hibisci, n. sp.

The body is cylindrical, rarely slightly spindle-shaped. In the female its length is, on the average, five times its breadth. The cephalo-thoracic shield is triangular and rounded at the anterior margin. Its lateral margins are more or less bent outwards and incompletely cover the proximal joints of the legs. The markings on the shield are very simple and distinct; they consist of three longitudinal lines near the middle, the central one running in the median line of the shield from the anterior to the posterior margin; the two exterior converging closely in front and bending obliquely inwards at the posterior margin. On each of the lateral portions of the shield can usually be seen two shorter curved lines, nearly parallel to the lateral margin; the outer one being longer than the inner, and generally bent obliquely inwards at its hinder end. The knobs from which the dorsal setae spring are large, hemispherical, and fairly distant from each other on the posterior edge of the shield, but do not project beyond it. The dorsal setae are a little longer than the shield, fine, and directed backwards.

The rostrum is small, slightly bent, directed obliquely forward, and at its base is covered by the anterior margin of the shield.

The legs are fairly long and weak, the two distal joints (tarsal joints) are of almost equal length. The claws are slightly bent and those of the second pair of legs are somewhat longer than those of the first.

The sternum is not forked posteriorly and reaches as far as the inner angles of the epimera. The first two thoracic setae are inserted a little in front of the anterior end of the sternum: the second pair are inserted well in front of the inner angles of the epimera on the sides of the sternum at about its middle.

The abdomen is cylindrical and tapers in its posterior third, ending in a small but distinct caudal lobe. On the back sixty to sixty-two rings can be counted: they are mostly narrow and uniformly marked with fine dots, but towards the posterior end they become gradually, though inconsiderably, broader and lose their dots on the dorsal side, so that about twenty of the rings in front of the caudal lobe are smooth dorsally. On the ventral side of the abdomen the rings are a little narrower and their dotting is finer and closer. The lateral setae are inserted somewhat posterior to the epigynium, are very fine and nearly as long as the third pair of ventral setae. The first pair of ventral setae are, at most, about one and a half times as long as the shield, and very fine towards the end. The second pair of ventral setae are remarkably short; they have about the same length as the genital setae and are far apart. Their distance from the first pair of ventral setae is not quite as great as that of the latter from the lateral setae. The third pair of ventral setae attain the same length as the shield and are stout. On the dorsal side of the caudal lobe are the insertions of the lash-like caudal setae, and of the short spike-shaped accessory setae: the former have very flexible thin ends and do not quite equal a third of the body length.

The epigynium lies directly behind the outer angles of the epimera, at the beginning of the abdomen. It is 0·018 mm. broad, not projecting, and basin-shaped: the covering lobe is striped lengthways. The genital setae are inserted laterally and are very short. The epiandrium is 0·016 mm. broad, shaped like a flattish arch.

The average length of the female is 0·18 mm., and the average breadth 0·036 mm.; the average length of the male is 0·15 mm., and its average breadth 0·035 mm.

Eriophyes hibisci produces bulgings of the leaf-blade in *Hibiscus rosa-sinensis*, L., which usually project on the upper side, less often on the under. The simplest forms of these are shallow hollows, which become deeper and baggy, project on the other side of the blade, and are often constricted at the mouth. These galls are from 1·5 to 5 mm. and more across and vary in shape: they are usually rounded, button-shaped, and flattened or somewhat depressed above: but lengthened forms, sometimes with very crooked longitudinal axes, are frequently found. Their surface is glabrous, and finely wrinkled: their colour cannot accurately be told from preserved material, but is not strikingly different from that of the leaves. These galls occur on the edge of the leaf as well as nearer the centre of the blade and are found singly or in groups. In the latter case, they fuse together to form large, irregular masses with knobby surfaces. The cavity of the gall is, in a few cases, a simple hollow, whose surface is clothed with hairs, and which communicates with the exterior by a wide mouth; but in

most cases many peg- and band-shaped excrescences spring from the interior wall, which often coalesce and become covered with one-celled, pointed, colourless hairs. These growths usually nearly fill up the primitive cavity of the gall, leaving narrow irregular crevices and passages, which are lined with hairs and inhabited by the gall-mites. In badly infected plants similar excrescences appear on the stems, the petioles, and the leaf-ribs. They take the form of spheroidal, or wart-like galls and appear singly, in rows, or in clusters. In the last case they usually coalesce to form shapeless masses and often deform the whole of that part of the plant (petioles and stipules). They are quite solid, with hairy surface, and have numerous furrows and irregular hollows, in which the mites live.

Those galls (cecidia) of malvaceous plants which have been previously investigated, include the malformations of the terminal buds, wrinkling and rolling up of the leaf-edges of *Malva Alcea*, L. (Frauenfeld, 1870) and of *Malva moschata*, L. (Geisenheyner, 1902), and the excrescences of *Gossypium barbadense* (Ballou, 1903) which are beset with a coat of hairs (erineum). Canestrini investigated the cecidium of *Malva Alcea*, L., and described as its cause a new species of gall-mite, which he named *Phytoptus malvae* (Canestrini, Sopra due nuove specie di Phytoptus. *Atti del R. Ist.*, Venice, 1891). Subsequently Canestrini reduced this name to a synonym, regarding the mite in question as identical with *Phytoptus geranii*, Can., which he had found on *Geranium sanguineum* (Canestrini, *Prospetto dell. Acarofauna ital.*, 1892, p. 674). I have not had an opportunity to test the correctness of this view, but considering the different nature of the host plants. I am of opinion that it is a mistaken one. It seems far more probable that the *Eriophyes* which lives on *Malva Alcea*, L., is *E. gymnoproctus*, Nal., which I found on *Malva moschata* (Nalepa, Neue Gallm., 21, Fortsetzung, *Anzeiger d. kais. Akad.*, Vienna, 1902, p. 17). The cecidia of *Gossypium barbadense* have as yet only been noted on cultivated plants, and were observed in 1903 at Montserrat (and later at St. Kitt's and St. Lucia). Ballou was the first who investigated them and showed that they were due to a species of *Phytoptus* (Ballou, Insects attacking Cotton in the West Indies, *West Indian Bulletin*, 1904, Vol. IV, p. 282). Ballou announced in his interesting article that Mr. Banks had determined this *Phytoptus* to be a new species and would describe it under the name of *Eriophyes gossypii* (loc. cit., p. 282). Since, on account of the close relationship of the host plants and the resemblance of the galls, there appeared to be a possibility that the galls of Gossypium and Hibiscus might be caused by one and the same species of gall-mite, I had, in the lack of a diagnosis of *Eriophyes gossypii*, to acquire a knowledge of this organism by personal observation. This was made possible through the kindness of Sir Daniel Morris, who forwarded to me well-preserved material of Gossypium galls. A direct comparison of their mites with those from the Hibiscus showed at once that the two differed in important characteristics. *E. hibisci* is distinguished from the species living on cotton chiefly by the different markings on the shield, the remarkably short pair of second ventral setae, the possession

of accessory caudal setae, and the absence of dots on the dorsal side of the posterior third. It cannot be asserted that *Eriophyes hibisci* is incapable or capable of living on cotton plants and causing galls on their leaves; for, so far as my knowledge extends, no infection experiments have hitherto been made, nor have any galls containing *E. hibisci* been noted on Gossypium.

I received my first information as to Hibiscus galls from Mr. W. E. Collinge, who was kind enough to send me some leaves covered with these galls. I was, however, only able to make a complete investigation of them when I had at my disposal the abundant and well-preserved material which Mr. C. H. Knowles collected near Suva, Fiji, and most willingly handed over to me. According to a communication from Dr. K. Rechinger, Assistant at the Royal Museum in Vienna, who was so kind as to determine the Hibiscus leaves forwarded, they are from *Hibiscus rosa-sinensis*, L.

I found isolated individuals of one of the Eriophydae of the genus Oxypleurites, lodging in the Hibiscus galls already described. This differs from known European species of the genus in the position of the shield-setae at the anterior edge of the shield. As I have examined as yet but two females, I cannot give a full description of this new species. Its most important characteristics are:—

Oxypleurites bisetus, n. sp.

Body compressed, flattened ventrally, broadest behind the shield. Shield large, nearly rectangular, completely covering the proximal leg-joints and the rostrum; the anterior edge with a tooth-like projection over the rostrum. The shield-setae short, inserted at the anterior margin of the shield and directed forwards. Legs short, stout, the first pair stouter. First joint of tarsus nearly twice as long as the second. Claws knobbed. Abdomen evenly tapered from the posterior edge of the shield, about twice as long as the latter. One to ten dorsal half-rings are broad, projecting laterally like teeth; four to five rings, anterior to the caudal lobe, are complete and narrow.

Ventral side flattened, widely furrowed, smooth. The first and second pair of ventral setae seem to be absent. Caudal lobe very small. Caudal setae very short. No accessory setae. Epigynium large, hemispherical. Length of the female, 0·15 mm.; breadth, 0·075 mm. Solitary in the galls of *Eriophyes hibisci* on *Hibiscus rosa-sinensis*, L.

Preparation and Preservation of Gall-mites.

The following information is abstracted from an article by Professor Nalepa in *Marcellia*, an international review of Cecidology, 1906, Avellino, Italy:—

These organisms cannot be mounted as permanent microscopic objects. In mounts of resinous material they soon lose their structural details, and in aqueous media containing glycerine, they become opaque and fat-drops appear. The best

method of preserving them is to free them from their galls while alive, fix them with picric acid, and keep them in tubes of alcohol.

Neither the oldest nor the youngest galls contain most mites. The mites leave the galls when the latter become so dry as not to yield the juices on which the gall-mites subsist. Hence galls which are still juicy must be selected. The selected galls are removed from the leaves, etc., with a sharp knife or razor, and cut across. Galls with a felt of hairs are cut into very narrow strips. The pieces are put on the bottom of a glass vessel, 8 inches high, which has been smeared with glycerine inside, 2 inches below the mouth. The vessel is put in a dry place in the dark, and the drying hastened, in damp weather, by covering it with a bell-jar, and putting calcium chloride under the bell-jar. The vessel may be occasionally rotated so that the layer of pieces of galls, which should be less than 1 inch deep, can be mixed up and the pieces at the bottom brought to the top. After twelve hours most of the mites will have crept out. If they are not seen on the sides of the glass with a pocket lens magnifying twenty diameters, there has been a failure. If, after twelve hours, mites are seen on the sides of the glass vessel, then a solution of 100 parts of water (or better, 94 per cent. alcohol), 2 parts of concentrated hydrochloric acid, and picric acid to saturation, is diluted with water to five or six times its bulk, heated to 120° F. to 140° F. and poured into the glass cylinder. The pieces of gall are then shaken with this solution, allowed barely to settle, and the liquid, which contains many of the free gall-mites in suspension, is poured off. The process is repeated. The liquid is then allowed to settle, poured off, and replaced by alcohol. If wire sieves, from $\frac{1}{2}$ mm. to $\frac{1}{10}$ mm. in mesh, can be obtained, the mites can be separated by these from the larger fragments of galls. They can be separated from sand particles by allowing the latter to settle and pouring off the liquid before the mites have settled.

The mites can be kept in flat-bottomed tubes, 3 inches long and $\frac{3}{5}$ inch wide, in 80 per cent. alcohol. The corks of these tubes should have been soaked in melted paraffin wax.

When required for study, a little of the sediment in the tubes can be taken up with a pipette and put on an object slide. Good solutions to clear the tissues are: 5 to 10 per cent. acetic acid with a little glycerine, aqueous or alcoholic solutions of phenol, or 2 to 5 per cent. solution of formalin.

ERRATA IN THE PRESENT VOLUME.

Page 22, line 2, *for* 'nulled' *read* 'milled.'
,, 48, ,, 42, *for* 'latera' *read* 'lateral.'
,, 69; ,, 11 from bottom, *for* 'medium' *read* 'median.'
,, 168, column 10, *for* 'grms.' *read* 'mm.'
,, 186, line 18, *for* 'casually' *read* 'causally.'
,, 203, last line of last column, *for* '6·94' *read* '16·94.'
,, 205, in heading of second and fifth columns of table, *for* 'grain' *read* 'gain.'
,, 213, line 6, *for* '*Solonaceae*' *read* '*Solanaceae.*'
,, 213, line 14, *for* 'genus' *read* 'order.'
,, 213, line 6 from bottom, *for* '*tetrogonum*' *read* '*tetragonum.*'

Pages 302 and 303, column 9, itemized figures to be transferred to column 8.

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